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ANNUAL REPORT
OF THE
GEOLOGICAL SURVEY
OF
ARKANSAS,
FOR 1888,
IN FOUR VOLUMES:

- VOL. I. ADMINISTRATIVE REPORT.
REPORT UPON THE GEOLOGY OF WESTERN CENTRAL ARKANSAS, WITH
ESPECIAL REFERENCE TO GOLD AND SILVER.
VOL. II. THE NEOZOIC GEOLOGY OF SOUTHWESTERN ARKANSAS.
VOL. III. THE GEOLOGY OF THE COAL REGIONS.
VOL. IV. MISCELLANEOUS REPORTS.

By JOHN C. BRANNER, Ph. D.,
State Geologist.

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1888.

VOL. II.

THE NEOZOIC GEOLOGY OF SOUTHWESTERN ARKANSAS.

By ROBERT T. HILL, Assistant Geologist.

APPENDICES.

THE NORTHERN LIMITS OF THE MESOZOIC ROCKS IN ARKANSAS.

By O. P. HAY, Assistant Geologist.

ON THE MANUFACTURE OF PORTLAND CEMENT.

By JOHN C. BRANNER, State Geologist.

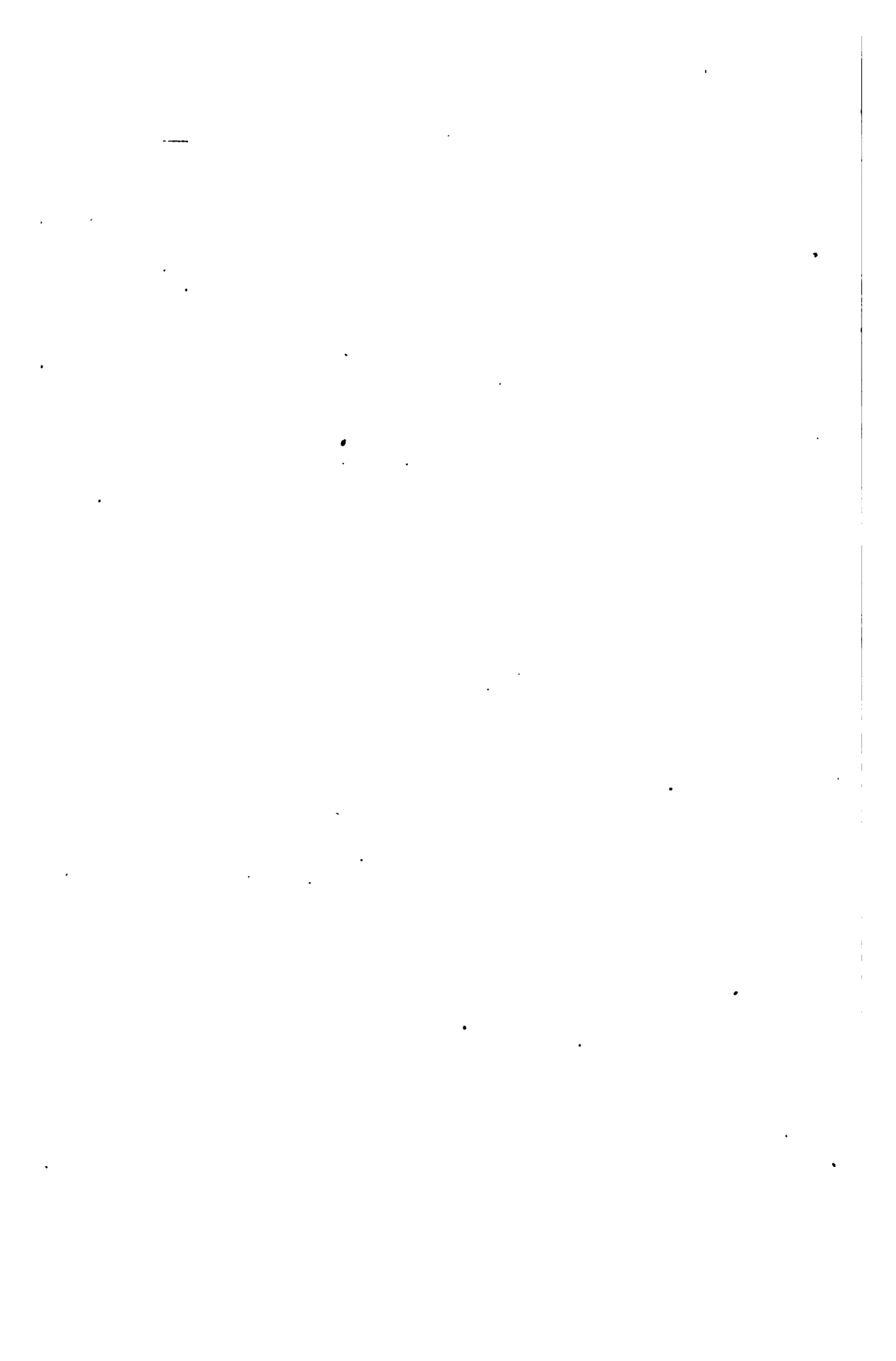


TABLE OF CONTENTS.

INTRODUCTION.

THE NEOZOIC GEOLOGY OF SOUTHWESTERN ARKANSAS.

By ROBERT T. HILL.

STRUCTURAL GEOLOGY.

CHAPTER I.

<i>The Geographic and Geologic Position of the Region.....</i>	1
The neozoic addition	2

CHAPTER II.

<i>Salient Topographic Features.....</i>	10
The drainage system.....	14
The Ouachita drainage.....	17
The flood plains or bottoms.....	19

CHAPTER III.

<i>Fundamental Stratigraphy.....</i>	24
--------------------------------------	----

CHAPTER IV.

<i>Formations of the Post-Tertiary</i>	28
The Red river loess	29
Prairie d'Ane or white clay till	32
The plateau gravel	35

CHAPTER V.

<i>General Conclusions on the Quaternary.....</i>	43
The hummocks or second bottoms	47

CHAPTER VI.

<i>The Tertiary</i>	48
The Camden series.....	49
The Arkadelphia shales	53
The Bingen sands.....	56
The Cleveland county red lands.....	58
Conclusions concerning the Camden series.....	59

CHAPTER VII.

<i>The Cretaceous Group.....</i>	66
----------------------------------	----

CHAPTER VIII.

<i>The Upper Cretaceous Series.....</i>	70
Divisions of the upper cretaceous.....	72
A. The upper arenaceous beds.....	72
B. The Chalky marl beds	84

CHAPTER VIII.—*Continued.*

1. The Washington or High Bluff greensand beds.....	72
2. The blue sands of High Bluff and of Pate's creek.....	73
3. The Big Deciper calcareous sands.....	77
3a. The Clark county littorals.....	79
3b. The Koster "joint clays".....	81
4. The Marlbrook-Columbus or Gryphæa vesicularis chalk marls.....	84
5. The Brownstown or yellow Exogyra ponderosa marls..	86
6. The White Cliffs chalk.....	87
6a. The White Cliffs sub-chalk.....	88
The Morris ferry greensands.....	89
The Rocky Comfort chalk.....	89

CHAPTER IX.

<i>General Conclusions on the Upper Cretaceous or Exogyra Costata Series.....</i>	96
---	----

CHAPTER X.

<i>Relation of the Upper Cretaceous of Arkansas to that of Other Areas</i>	98
I. Relation to the Texas region.....	98
II. Relation to the northwestern United States.....	101
III. Relation to the Mississippi-Alabama region.....	102
IV. Relation to the New Jersey area.....	105
General relation to other regions.....	107

CHAPTER XI.

<i>The Lower Cretaceous or Comanche Series.....</i>	110
The Washita division.....	111
The Fredericksburg division.....	111
General remarks on the Comanche above the Trinity.....	113

CHAPTER XII.

<i>The Lower Cretaceous continued.....</i>	116
The Trinity division.....	116
The Trinity division in Texas.....	121
The stratigraphic position of the Trinity.....	123
Thickness of the Trinity.....	123
The color of the Trinity beds.....	123
Origin of red sandstone and rock salt.....	123
Relations to other areas.....	125

CHAPTER XIII.

<i>Paleontology of the Trinity Division.....</i>	127
Invertebrates.....	128
Vertebrate remains.....	152
Vegetal remains.....	152

CHAPTER XIV.

<i>Chalk in the North American Cretaceous.....</i>	153
--	-----

CHAPTER XV.

<i>Resume of the Cretaceous Group</i>	163
---	-----

CHAPTER XVI.

<i>Events Recorded in the Neozoic Deposits of Southwestern Arkansas</i>	175
I. The Trinity division.....	176
II. The Comanche or lower cretaceous series.....	176
III. The upper cretaceous series.....	177
IV. The Camden lignitic or basal tertiary.....	177
V. The post-tertiary or quaternary deposits.....	177
Evidences of stratigraphic breaks.....	178
Paleontologic.....	178
Stratigraphic.....	178
The ages of the different formations.....	179
History recorded in the neozoic formations.....	182
Synoptical table of the neozoic formations of southwestern Arkansas.....	188

CHAPTER XVII.

ECONOMIC GEOLOGY.....	191
Introduction.....	191

CHAPTER XVIII.

<i>The Origin of Soils</i>	194
----------------------------------	-----

CHAPTER XIX.

<i>The Classification of Soils</i>	199
The distribution of soils.....	200

CHAPTER XX.

<i>The Transported or Exogenous Soils of Southwestern Arkansas</i> ...	203
--	-----

CHAPTER XXI.

<i>The Residual Soils of Southwestern Arkansas</i>	207
The soils of the post-tertiary gravel and red lands.....	208
The soils of the Camden series.....	209
The soils of the upper cretaceous.....	213
The soils of the High Bluff or Washington sands.....	213
The soils of the Big Deciper formation.....	215
Marl soils.....	215
The sandy post oak lands, or mulatto sands.....	217
The soils of the Rocky Comfort chalk.....	217
The Gryphæa pitcher clay soils.....	218
Soils of the Trinity formation.....	218
Table of rock and soil analyses.....	220

CHAPTER XXII.

<i>The Amelioration of Soils</i>	222
--	-----

CHAPTER XXIII.

<i>The Mixing, Marling and Chalking of Soils</i>	225
Marls and marling	225
The agricultural uses of greensand marls	227
The value of greensand marls.....	228
The agricultural marls and chalks of Arkansas	231
I. The tertiary marls of eastern Arkansas.....	232
II. The cretaceous marls of southwestern Arkansas.....	232
The upper cretaceous or greensand marls.....	233
Table of analyses of greensand marls.....	235
Comparative analyses of lime marls.....	237

CHAPTER XXIV.

<i>The Agricultural Uses of Chalks and Chalky Marls</i>	239
Application of lime	239
Gypsum and gypsiferous marls.....	240
Phosphatic marls.....	241

CHAPTER XXV.

<i>Methods of Using Marls</i>	246
Limited duration of the effects of marling	246
Marling	247
Overdressing with marl	249

CHAPTER XXVI.

<i>Hygiene and Disinfecting Results of Marling</i>	250
Gypseous marls.....	250
Use of marls in composting	251
Applicability of Arkansas marls to the soils, and the necessity of experimentation.....	252
Concluding remarks on marls	253

CHAPTER XXVII.

<i>The Economic Products of the Region</i>	255
The forests	255
Tree culture.....	255
Iron ores	256
Clays	256
Building material	257
Gypsum	257
Salt and salines.....	258
Lignite or brown coal.....	258
Mineral Springs	259

CHAPTER XXVIII.

THE NORTHERN LIMIT OF THE MESOZOIC ROCKS IN ARKANSAS,

By O. P. Hay	261
General features of the northern border of the mesozoic.....	262
The mesozoic border across Clark county.....	264

CHAPTER XXVIII.—*Continued.*

The mesozoic border across Pike county.....	278
The mesozoic border across Howard county.....	284
The mesozoic border across Sevier county.....	287

CHAPTER XXIX.

ON THE MANUFACTURE OF PORTLAND CEMENT,

By John C. Branner	291
What is Portland cement	292
The raw material.....	293
Chalk	293
The extent of the chalk deposits of Arkansas	295
The clays	295
Grinding and mixing the raw material.	298
Burning	302
Grinding the clinker.....	301
Testing the cement.....	301
The uses of Portland cement	302
Imports of cement at New York.....	302

ERRATA.

PAGE.	LINE.	
4	12	"of" should read <i>or</i> .
12	20	"Norwoodville" should read <i>Chapel Hill</i> .
21	13	"depends upon" should read <i>varies with</i> .
24	5	"Jurassic" should read <i>Jurassic</i> (?)
61	11	"All" should read <i>most</i> , and "Block" should read <i>Black</i> .
72	22	Insert <i>glauconitic</i> before "chalk marls."
75	2	of foot note. " <i>Caelianassa</i> " should read <i>Calianassa</i> .
75	3	Omit "sp. ind." after " <i>Ostrea larva</i> ."
76	3	of foot note. " <i>Bovatus</i> " should read <i>B. ovatus</i> .
80	16	" <i>Pecten quinquecostata</i> " should read <i>Pecten sp. ind.</i>
82		Last line of foot note. " <i>rechlabrum</i> " should read <i>rectilabrum</i> .
90	21-22	"direct antecedent" should read <i>deep sea culmination</i> .
90	23	"differences" should read <i>peculiarities</i> .
91	26-27	"sharper and bolder" should read <i>gentler</i> .
94	12	Strike out "below" and " <i>Niobrara</i> ."
99	9	"Schutt" should read <i>Schott</i> .
121	30	"greensands" should read <i>greenish sands</i> .
128	22	Omit "and well defined."
130	27	"to be" should read <i>may be</i> .
132		"De Leriol" should read <i>De Loriol</i> .
156	15	Add <i>sometimes</i> before "igneous metamorphism."
166	7	of table. " <i>Gryphæa sinuata</i> Sow. (Mor.)" should read <i>Gryphæa sinuata Marcou</i> .
176	5	of second foot note. " <i>Juromen</i> " should read <i>Turonien</i> .

INTRODUCTION.

The body of the present volume by Professor Robert T. Hill is the result of the joint work of the United States Geological Survey and of the Geological Survey of Arkansas.^{*} By this co-operation the Arkansas Survey has received the benefit of Professor Hill's knowledge of the mesozoic geology of other parts of the Union, and has been able to study the geology of a portion of the State which, without the aid of the National Survey, could not have been undertaken, for the present at least.

The geology of the Southern States, and notably that of the cotton growing portions of the South has never received the attention to which it is entitled. This neglect has doubtless been due to two principal causes: the absence of minerals of economic importance, for the discovery and development of which geological surveys are supposed to originate and exist; and the obscurity and difficulty of its geologic problems. In so far as Southwestern Arkansas is concerned, the first mentioned difficulty, if it existed, has been overcome by the co-operation of the State and National Surveys; and the second has been overcome by the indefatigable zeal and insight of Professor Hill, the author of the volume.

The difficulties encountered by Professor Hill in the prosecution of this work have been of no trifling character. The lack of good geographic maps has been most seriously felt. The only maps that have been available at all are the old cadastral maps, upon which no other topographic features than the meanderings of streams are represented, and in a great many instances even these meanderings have greatly changed since the maps were made. With the exception of a few small prairies, the whole region is covered by heavy forests and dense

undergrowth, while even the broader features of geologic sub-structure are further obscured by widespread post-tertiary deposits. Even where the mesozoic rocks have been exposed, their unconsolidated character, the deceptive changes by disintegration and discoloration through which they pass upon exposure, the absence of fossils from many of the beds, and the lithologic similarity between horizons as widely separated as the lower cretaceous and the post-tertiary, make the region a difficult one to study satisfactorily.

As far as Arkansas is concerned this work had to be done too *ab initio*. A few desultory notes upon the mesozoic geology of the State made by Dr. Owen represented the only published data upon the geology of the region here discussed when this work was taken up.

It is a most agreeable duty, however, to recognize, in this connection, the value of Dr. Eugene W. Hilgard's writings upon the mesozoic and cenozoic geology of the Southern States. Every one who undertakes serious geologic work in this portion of the country must necessarily be impressed with the ability with which his work was done and the general correctness of his deductions.

With the time and means at the command of the Geological Survey it has been impossible to enable Professor Hill to make this report exhaustive. The results obtained, however, aside from their economic value, throw much light upon the geologic history and structure not of this State alone, but of our continent.

From an economic point of view this part of the Survey's work has been more valuable than was anticipated. It is true that metallic minerals have not been discovered, and indeed it is not to be expected that they exist in these mesozoic rocks. On the other hand, however, this portion of the State is fortunate in the possession of chalks, gypsum, and greensands, and of remarkably fine agricultural and timber lands.

The origin and classification of the soils of the region, and the suggestions regarding the preservation and amelioration of these soils as given in this report cannot fail, if properly car-

ried out, to be of the greatest value to the State, and especially to the people of the region here discussed. Similar sources of agricultural profit have enriched other portions of the country, and there is no reason why they should not enrich ours if only the proper use be made of them.

The black lands of Arkansas are notoriously fertile, many of the fields in the black lands having produced crops for thirty years consecutively, and that too without any fertilizing or rest whatever. This fertility is due to the fact that these soils are derived from the decay of chalk or limestone and of organic matter. Nature offers us here an object lesson which should not be overlooked.

The soils of a large portion of Arkansas are more or less deficient in lime. All such would be greatly benefited by the application of the chalk which occurs in such abundance in the southwestern part of the State.

The system of agriculture by which the natural fertility of land is exhausted and the land abandoned cannot long recommend itself to the intelligence of our farmers. It must be realized ere long that it requires more work and more "hands" and is less profitable to cultivate a large farm poorly than to cultivate a small farm well. When this is realized we shall, instead of exhausting and abandoning our farms, return to them something of what they yield to us.

In the summer of 1887 Dr. O. P. Hay, of Butler University, Irvington, Indiana, and Mr. Chas. H. Bollman, of the University of Indiana, volunteered their services upon the Survey, and spent a couple of months in tracing the northern limits of the mesozoic rocks of the State from the Ouachita river near Arkadelphia to the Indian Territory. The results of their work are given in the appendix by Dr. Hay on pages 261 *et seq.*

The existence of chalk in the State having interested the people in methods of utilizing it, a brief chapter upon the manufacture of Portland cement is also appended.

The map accompanying this volume is compiled from the old United States land surveys. In a few cases the roads have been meandered, but for the most part they have been located

by information obtained from trustworthy citizens, while the railways have been located by information received from the railway offices.

JOHN C. BRANNER,
State Geologist.

NEOZOIC GEOLOGY OF SOUTHWESTERN ARKANSAS.

By ROBERT T. HILL, ASSISTANT GEOLOGIST.

PART I.

STRUCTURAL GEOLOGY.

CHAPTER I.

THE GEOGRAPHIC AND GEOLOGIC POSITION OF THE REGION.

The State of Arkansas is not a convenient unit for the description and discussion of natural phenomena, for its political boundaries do not agree with those of nature. Upon the contrary, its broader geographic and geologic features, instead of being local and characteristic, are but continuations of similar features and formations from adjacent political divisions. In fact, its neozoic geology is chiefly interesting to the geologist because it is the transition ground of many formations peculiar to the eastern and western United States.

If artificial, political and commercial divisions could be forgotten, and the reader should subdivide, according to its natural features and conditions, all that portion of the United States east of the great plains at the base of the Rocky Mountains, he would find the following two striking divisions:

First: A higher interior region underlain by a firm rock structure of ancient, dark colored, crystalline limestones, sandstones, slates and granites, which may be approximately horizontal, as in central New York and Ohio, or highly folded and distorted, as in the Appalachians and the mountainous regions of southwestern Arkansas.

Second: A newer, lower coastal belt, lying between the older interior region already described and the present borders of the ocean, which, in general, is underlain by and composed of softer unsegregated strata of marls, clays, chalks, sands and gravels. Firm rock strata are exceptional in this latter division, and, when found, occur in the older and lower portion of the series, and near the border of the old continental area. The strata are nearly horizontal, seldom dipping perceptibly, and when the dip is apparent it is approximately in the direction of the present coast line.

Each of these broad regions can, in itself, be greatly subdivided, but the boundary between these two is one of the most important lines of demarkation in the geological history of our continent. The interior continental area was elevated from the water an infinite length of time before the newer coastward slope, so that the latter can be better conceived as an addition to our continent, made long after the main portion was finished. The rocks of the older interior portion will be distinguished in this work as the paleozoic, and the newer as the neozoic addition.

The older, interior, continental area includes the entire Appalachian mountain system, the basin of middle Tennessee, Kentucky, Ohio, Indiana, Illinois, Iowa and Missouri, and the mountainous regions of the Indian Territory, Missouri, Arkansas, and the narrow strip of Texas between the 98th and 100th meridians, and north of the San Saba river. It is only the coastward border of this older region that has any bearing upon the topics discussed in this paper, and it will be better understood after defining the neozoic addition.

THE NEOZOIC ADDITION.

This neozoic addition may be imagined as an approximately level, subcrescent shaped strip of land lying along the eastern oceanic border of our country from northern New Jersey to Mexico, tapering from zero at its extremities to a width of about five hundred miles at its center, between the mouth of the Mississippi and Cairo, Ill., and the southern

point of Florida and near Macon, Georgia. The interior border of this region approximately divides the coast states, except Florida and Louisiana, which are wholly within it, into the two widely different varieties of country above described, further locally distinguished as the mountains and the lowlands. This border rounds the southern terminus of the Appalachian system in northern Georgia, Alabama and Mississippi, follows the line of the Tennessee river, from where it touches the last named state, northward into southern Illinois, crosses the Mississippi near Cairo, and runs southwest through Arkansas,* as far as Arkadelphia. Thence it is deflected westward into Indian Territory and Texas, along an irregular line which it will be a portion of our task to define, and which, owing to several new factors in the geologic problem, here assumes an aspect different both geologically and geographically from that of its continuation east of the Mississippi river.

The most salient physical features of the neozoic addition are:

First, its generally low altitude which, east of the Iron Mountain railway, seldom exceeds 400 feet along its interior border, being only 322 feet above tide at Cairo, some 500 miles from the gulf, and 380 feet at Little Rock.

Second, the gentle undulations and comparative flatness of its surface.

Third, the width, sluggishness and unstable character of the channels of its rivers, which meander over wide areas of country.

Fourth, the density and luxuriance of its timber growth.

Fifth, the horizontality, friability, and unconsolidated condition of its fundamental strata, which are usually inconspicuous and devoid of massive rock structure.

Sixth, the freshness in appearance of its fossil remains, the shell substance often being as well preserved as it is in those found on our present seashores.

*The portion of this line south of Cairo has never been delineated previous to the work done by this Survey.

The natural aspect of the older continental area is in bold contrast with that of this neozoic addition. Its altitude increases suddenly nearly everywhere to over a 1000 feet along its coastward border from the level of that of the interior margin. Its surface is usually broken and rugged, often mountainous, and presents sharp outlines of hills and scarps. Its clear and rapid streams are confined in narrow channels with rocky sides and bottoms, while its fundamental strata are hard, resisting, massive rocks, disturbed and projecting so as to form conspicuous surface features. The fossil remains of these beds belong to forms of life long since extinct, and are preserved only as faint impressions of casts, with but little trace of their original shell substance.

The features of the interior region are those of old age, substantiality, consolidation and resistance to denuding agencies. Its sediments have undergone great chemical and physical changes since their original deposition, having been altered by forces, acting through an almost infinite period of time. The features of the coastal slope are those of unconsolidation and newness, their structure consisting mostly of soft and unconsolidated chinks, marls, sands and clays, which constantly call to mind the conditions of sedimentation now in process in our oceanic waters.

In other words, the phenomena of the neozoic addition are mostly those of the present, such as oceanic sedimentation, and physical and chemical changes of more familiar character. Those of the interior are all these, plus an infinite factor of time, accompanied by great consolidation and distortion of the strata. From the decay of the old much of the new has been built. The extension of the shore line oceanward has therefore been at the expense of the denudation of the interior.

The interior region or its coastward margin will be recognized as the seat of most of the large inland cities, the quarrying, mining, manufacturing and small agricultural industries of the mountainous districts of our country; and the neozoic addition, at least that portion embraced in the Gulf States, is

the region of large plantations, more familiarly known as the "cotton belt."

The rocks of the interior region were formed in that ancient era of the earth's history technically termed "paleozoic," while those of the neozoic addition were formed during the mesozoic and cenozoic, or middle and later geologic times, the collective name of which it bears.

Though this new addition to our continent conforms generically to the description given above, it presents an infinite variety of minor topographic and geologic aspects, which, through intergradation and community of generic features, are difficult to define without first understanding the underlying stratigraphy upon which they depend. The terranes and formations are fewer and more easily distinguished in New Jersey and Maryland, and increase in number as we go southward, making the local variations less distinct and more difficult of diagnosis; while the differential elevation which the continent has undergone, north and south, has produced great difference in the geographic distribution of the same geologic formations, and in the physical conditions attending their depositions.

In general, however, there are two longitudinal divisions of the neozoic addition, which, although obscure and intermittent, are more or less perceptible throughout its entire length. One of these is an elevated region which lies at the border of the old interior continental region, while the other, and more extensive one, occupies the lower flat lands coastward.

The north Atlantic portions of these divisions have recently been defined by Mr. W. J. McGee, Mr. Gilbert Thompson and others as the "Piedmont plateau" and the "coastal plain,"—subdivisions which cannot be extended in their application to the Arkansas-Texas portion of the neozoic addition, except with great modification. The line of demarkation between these is known as the "fall line of the rivers" in the North Atlantic states, which, as McGee has said, "is one of the most strongly marked physiographic and cultural lines on the surface of the globe."*

*American Journal of Science, Feb., 1888, p. 122.

What is known of this fall line east of the Mississippi has been partially defined by Mr. Gilbert Thompson.*

This line becomes less distinguishable southward, so that instead of a constant fall line there are many rapids extending over a long distance of the river's course.

The coastal plain embraces all the country between this fall line and the present coast. According to Mr. McGee it "extends from the line of cataracts to the ocean. Structurally it consists of generally incoherent deposits of the later mesozoic and cenozoic age, slightly inclined seaward, but otherwise undisturbed; topographically, it is a plain trenched by broad but shallow tidal estuaries, and thus separable into smaller plains which sometimes undulate gently but irregularly, and again take the form of steeply scarped terraces, miles in extent, cut by deep sided ravines, and deeply scalloped along the the greater waterways. The hydrography comprises the broad, flat-bottomed estuaries into which the principal rivers are transformed on entering the plain, and local drainage systems of widely branching dendritic type in which the principals are also generally estuarian toward their mouths; the divides are but labyrinthine and crenulated remnants of an imperfectly drained plan, only partially invaded by erosion; and throughout the region the water is slack, except toward the heads of

*"If we follow the course of any river in the eastern part of the United States, south of New England, from its source to the sea, we discover that at a certain point it ceases to be rapid and turbulent, and becomes broad and slow moving, and in many cases an estuary of the sea. At this point where this change occurs there is usually a fall or rapid. The familiar local example is the Potomac at Little Falls. I have traced this fall line from near Troy, N. Y., southward by the interior cities of Washington, Richmond, Columbia and Montgomery, and thence to the Muscle Shoals of the Tennessee River. It is always the lower limit of water power and often the upper limit of navigation, and is therefore marked, and destined to be marked, by cities and towns of importance. In its northern portion it is at the head of tide, and nowhere does it exceed an altitude of 200 feet. It may yet be determined that it crosses the St. Lawrence at the Lachine Rapids and the Mississippi above Cairo, although no rapid exists at that point. Whether it may be traced farther and into Mexico remains to be determined."—Philosophical Society of Washington, April 24, 1886.

the adolescent drainage ways. The political boundaries and principal lines of traffic are independent of the physiography.”*

This local definition, with the exception that the streams are not necessarily tidal, applies to the continuous coastward strip from New Jersey to Mexico, including most of New Jersey, eastern Maryland, Virginia, Georgia and the Carolinas, southern Georgia, Alabama and Mississippi, western Tennessee and Kentucky, southern Illinois, eastern Arkansas and Texas, and all of Louisiana and Florida.

Inland of the coastal plain in the North Atlantic states, occupying the comparatively narrow interior border of the neo-zoic addition, often broken in its continuity, and resting against the interior ancient (paleozoic) continental area, is a very different topography. This becomes more broken, not mountainous, but of the nature of foot hills.

The southern homology of the Piedmontal plateau of the Virginias is doubtful and obscure, but in the cotton belt the neo-zoic addition, like it, is divisible into two equally well defined broad topographic areas, the lower coastal plain, and a higher interior region, clearly differentiated by distinct cultural and physiographic features. This interior region of the neo-zoic addition in the south is known as the upland portion of the cotton belt, being especially distinguishable by its black-soiled cretaceous areas embracing great extreme of geologic and economic conditions, including the noted black lands and flat-woods of Mississippi, Alabama, Arkansas and Texas, and several other characteristic features.

The head of navigation, or the fall line of the rivers, in the South, is not as constant a feature in this region as in the North Atlantic, but occupies different partings at different portions of its course. In the North Atlantic states it follows the partings of the upper cretaceous and the older mesozoics; in the northern portion of the western half of the Mississippi embayment it occupies the partings between the tertiary and the older paleozoic rocks; while in the region southwest from Arkadelphia to the Rio Grande the fall line ceases altogether as a sta-

*American Journal of Science, Feb., 1888, p. 122.

ble feature, and is replaced by a series of slight rapids that are obliterated in highest water.

The gulf portion of the neozoic area is divisible again geologically into the Mississippi embayment and the coastal border. The former represents the sum of the successive stages of the Mississippi's mouth from near Cairo, Ill., to the point where it became projectingly deltoid, near northern Louisiana, which includes all the northward narrowing neozoic area.

Instead of this margin being a regular unbroken line, however, as it is generally represented upon maps, there are several neozoic indentations in the margin of the interior paleozoic region. The most conspicuous of these indentations is that marked by the subsidiary drainage of Red river, extending up that stream, for the most part upon its north side, to the Pan Handle of Texas. The area to be described in this article is a small portion of this Red river indentation.

No portion of the United States is a more important field of geologic investigation than the Gulf states division of this Atlantic neozoic addition. It is the location of the great cotton growing industry, and upon it the great Atlantic timber belt reaches its culmination. But little has been done by geologists, however, toward the systematic study of this region, and that little was mostly done more than thirty years ago, since which time the methods and facilities for geologic investigation have been greatly increased. To this interior region of the neozoic addition, including its contact with the older continental outline on the one side and the coastal plains on the other, the southwestern counties of Arkansas belong.

No portion of this neozoic addition is more interesting or more worthy of economic study than that in the State of Arkansas. It includes within convenient distance a continuous section of the typical formation's lower coastal slope, the interior elevated region, and the old paleo-mesozoic parting, embracing a great diversity of interesting formations, from the study of which valuable data are deduced which will be of great service, not only to the immediate locality, but in throw-

ing great light upon the geology of the whole southern cotton belt.

This upland portion of the neozoic addition and its contact with the coastal plain upon one side, and the older continental region upon the other, is found in Arkansas, principally in the triangular area included in parts of Clark, Pike, Nevada, Hempstead, Howard, Little River and Sevier counties. In this limited area is found a greater diversity of geologic condition than in any other portion of the United States, and, consequently, a greater diversity of soils and of agricultural and mineralogic conditions. Here the peculiar mesozoic formations of the western United States make their final disappearance beneath those of the Gulf region, while the latter make their last westward appearance.

CHAPTER II.

SALIENT TOPOGRAPHIC FEATURES.

A view from the high ground a mile north of Centre Point, Howard county, reveals the leading topographic and geologic features of the interior portion of the neozoic area. Here the greatest altitude of the non-mountainous portion of the State is attained, 550 feet above mean tide level. The immediate ground is the fragment of an extensive plain, which once extended continuously over the region, gently sloping southward towards Red river from the base of the east and west mountainous ridge seen some twenty miles to the north, and called the "Ouachita system" by Dr. Branner. These are the mountains of the Indian Territory and Polk, Howard, Sevier and Pike counties, Arkansas, of which more will be said later on. When viewed from a distance of twenty miles these remarkable ridges, some of whose summits are nearly 3000 feet above tide, stand forth as sharply and majestically upon the landscape as do the Rockies above the Colorado plains.*

At Arkadelphia the parting between the neozoic addition and the paleozoic mountain region ceases to have a southwesterly direction, and is deflected sharply to the west for several

*These mountains are the most southern of that striking system of parallel ranges described by the State Geologist in his report. This particular one he has called the Ouachita range. It is neither possible nor in the province of this paper to describe this mountain system further than to say that collectively it continues intermittently in a westward course into the Choctaw, Chickasaw and Comanche nations to the 100th meridian, including in its trend the groups locally known as the "Seven Devils," the North Boggy and the Shawnee Hills, Kimishis, the Stringtown, the Tishomingo Potato Hills, the Arbuckle Mountains, the Wichitas and the Navajoes. The continuity of these mountains west of Arkansas is often broken, and their size becomes inconspicuous; more frequently their numerous tumuli, ridges, hooks, and other remarkable forms, baffle all attempts at systematization. In general, however, the trend of disturbance is a little south of west. This system, which has not hitherto been considered worthy of a place upon our maps, is one of the most important geographic and geologic features of our continent.

hundred miles to the vicinity of Tishomingo, in the Indian Territory, when it is again deflected southward through central Texas.

The cause of this deflection is found in this system of peculiar orographic wrinkles or mountains, traces of which first appear near the mouth of the Caddo, whence they extend westward. The great hardness, extent, and mass of this Ouachita mountain system, as appropriately named by the State Geologist, proved an insurmountable obstacle to the northward invasion of oceanic waters of the successive geologic epochs with which this paper deals.

Let us now examine more closely the plateau or plain, if its remaining fragments can be so termed. The mountains are clearly the northern limit of this plain, and from the nature of the coarse, rounded and stratified gravel composing its surface, it must be inferred that it is the remnant of the beach of an ancient sea, which beat against and greatly degraded the mountain ridges. If the extent and bounds of this gravel covered plain are sought they will be found to extend intermittently, but adjacent always to the mountain region, from Arkadelphia westward far into the Choctaw country, and that it always had a uniform slope. It will also be found that its continuity has been broken by the series of wide drainage valleys of portions of the Ouachita, the Saline, the Cossatot, and the fork of Little river, where they flow southward in the direction of its slope, and again in a direction at right angles to these by the streams which flow east and west, such as of portions of Red, Little rivers, and the Muddy fork of the Little Missouri. All of these latter streams have deep and wide valleys, so that the original plain is seen now only in the more or less extensive flat topped drainage divides, which increase in area from a mere remnant at the High bluff of the Ouachita, and in the town of Arkadelphia, to the extensive plain constituting the Little and Red river divide in southwestern Choctaw Nation.

From the same point of view may be seen another marked feature in the denudation of this gravel beach; the great east and west valley or valleys mentioned above, the forest covered

bottoms of which extend from the base of the scarp at our feet to the distant mountains on the north. This seems to be a great groove worn along the face of the plateau, at right angles to its slope, and parallel to the mountain range. The valley appears to be continuous, from the Ouachita to Little river, but occasional ridges break its continuity. The Caddo, the Little Missouri, Muddy fork, Messer's creek, a portion of Little river, the Boggy and other streams follow its course. Threading this valley is the old Little Rock and Fort Towson road, perhaps the most ancient and conspicuous artificial landmark in Arkansas, constructed long before the Anglo-American settlement of this region, for the purpose of moving the Choctaw people to their present reservation. The course of this road, as will be seen later, also approximately coincides with important geologic boundaries, marking the longitudinal extent of one important formation and the parting of the paleozoic and mesozoic rocks.

The southern wall or scarp of this peculiar east-west valley is also a conspicuous one. The county roads from Murfreesboro to Norwoodville, by way of Centre Point and Lockesburg, parallel to, and a few miles south of the old military road above described, skirts its margin. Often there are several terraces along the face of the scarp, which further study may systematize. As we descend into the valley northward from Centre Point, softer and more yielding beds of stratified sands, clays, gypsum, gypsiferous marls, and disintegrating limestones are found beneath the gravel plain. Along the northern side of the valley these softer sediments rest upon the upturned edges of firm brown quartzites, or sandstones, entirely different from any rock of the region exposed to the south or the east, and known throughout the county as "mountain rocks." These, with accompanying shales, underlie the region between the valley and the mountains proper. The main valley follows the line of contact between these "mountain rocks" and the overlying softer rock. In other words, these east-west valleys occur along a line of least resistance at the paleo-mesozoic parting, which was once entirely

obscured, but is now almost obliterated by the erosion of later waters, which have destroyed the overlapping gravel beach.

The southern and eastern margins of this plain have been greatly eroded and modified, first, by the encroachment from those directions of a still later marine invasion, and next, by the great erosion of the Red and Little river drainage.

Traveling along the plateau from Centre Point fifteen miles southward one finds another great valley of denudation with its accompanying terraces—that of Little and Red rivers. As seen at the village of Ben Lomond, the escarpment line is not so regular, but it runs southward in jagged points, averaging three hundred feet above the river. These points are the southward diminishing divides of Mine creek, Saline, Cossatot, and Rolling fork, streams which have cut through the ancient sea beach, and whose valleys widen towards their mouths, and reduce the southern edge of the plateau to a fringe or series of narrow divides. Here the gravel overlies an entirely different series of strata from those seen in the lateral valleys north of Centre Point. This is the great chalky formation described elsewhere as the *Exogyra costata*, or upper cretaceous series. In the valley below is an accompanying radical change in nature of soil, water, timber, and minor topographic features.

Southward and westward from these points the effect of denudation is grandly shown. From the chalk bluffs south of Brownstown, at the southern margin of the gravel plateau hundreds of square miles of lowland are visible, forming the present and past flood plains of the Red and Little rivers, over which these ridge and plateau features once extended.

Far across the valleys near Lewisville, some forty miles to the southeast, can be seen another high point, an outlying fragment of the gravel plateau.

From a point one mile north of Mineral Springs, Howard county, looking to the east, across the drainage depression of Mine creek, one sees a long and elevated region apparently the same altitude as that of the Centre Point gravel plateau. This is the divide between Mine creek and the Ozan, a tributary of the Little Missouri and of the Red river drainage. This divide

extends from the Little Missouri valley near Wallaceburg, in a southwest direction, to Saratoga, in Howard county. Although its western face appears abrupt, its eastern side is a series of decidedly rounded hills, which in turn, are succeeded by an extensive flat country known as the yellow clay pine flats, which continues to the east of the region included in this discussion. The highest line of this divide, approximately marked by the Columbus-Marlbrook road, traverses a country quite different in character from that of the top of the gravel plateau, and later on, it will be seen that this ridge is the remnant of another and later shore line. Tradition says that the crest of this Columbus-Marlbrook ridge, which is now all under cultivation, was once a continuous prairie. Fragments of it continue beyond the Little Missouri valley into Clark county at Okolona, Dobyville and Bozeman's, while the High bluff of the Ouachita just above Arkadelphia is also probably a remnant of it.

The upland country between the gravel plateau and the flatwoods of Gurdon, Hope and central Arkansas, presents, besides this drainage divide, a variety of topographic forms, including rounded sand hills and the water-sheds along the eastern margin of the gravel plateau. Besides the topography of the uplands, the bottoms or flood plains of the rivers, which probably occupy one-twelfth of the whole area, present one or more great terraces, which will be better understood after a discussion of the drainage system.

THE DRAINAGE SYSTEM.

The drainage, upon which most of the surface features are dependent, is complicated. The diverse direction of the many streams depends to a great extent upon fundamental stratigraphic features of the mountain country, which it is not in the province of this paper to discuss. The main arteries are the Red river and its principal branch, Little river, and the Ouachita and its principal confluent, the Little Missouri. These, with many secondary unnavigable streams, upon all of which the further economic discussion of the region depends, can only

be fully understood by taking a comprehensive view of the drainage of the entire eastern slope of the Rocky Mountains.

The streams of the eastern slope of the Rocky Mountains, according to their length and origin, consist of the following four well defined groups.

I. The Missouri, the Arkansas and the Rio Grande, form the first and most important group of this drainage. They originate in the highly disturbed Rocky Mountain region, and traverse many diverse intervening formations between their sources and their mouths. The sediments of their flood plains, especially within the cotton belt, constitute lands of great uniformity and fertility, containing nearly all the essential elements, both mechanical and chemical, of productiveness.

II. The Red, the Brazos and the Colorado, form the second group of the system. These streams originate in the rich quaternary loams of the summits and the gypsiferous red marls the eastern edge of the Llano Estacado, and, owing to the peculiar meteorologic conditions of that region, especially the sudden and voluminous summer rainfalls, deposit their rich sediments over the bottom of the neozoic addition. To this circumstance are due the rich, red bottoms of those rivers, which form a large proportion of the best sugar and cotton lands of Louisiana, Arkansas and Texas.

III. The Ouachita, the Trinity, San Marcos, Nueces and San Antonio, form the third group of these streams. They have their origin near a great stratigraphic nonconformity near the interior border of the upper cretaceous, either in the older mesozoic or paleozoic strata.

IV. The low tidal bayous of the coast, and the parallel streams of the Mississippi and Red river embayments, form the fourth group.

The overflows of the first and second systems are largely independent of local rainfall in Arkansas, while those of the third and fourth are entirely dependent upon it.

In the flood plains there are many smaller streams and pools which have a variety of phases. These are either the debouchement of streams from the upland, or former stream

channels. They are distinguished by the fact that the high waters from the rivers or ocean back up into them, and stand in pools or lakes. They are locally termed bayous. In the uplands, however, the flow of the secondary creeks is generally inconstant, especially in the porous sandy regions. There are no true lakes in southwestern Arkansas. Bodies of enclosed fresh water of considerable extent, resulting from overflow of the rivers, and standing in their flood plains, and in local expansions of creek beds and bayous, are sometimes called lakes, but there are no real upland basins or depressions retaining water. The so-called lakes of the bottom are "cut offs" or abandoned river channels of very recent date, filled at time of overflow, and remaining so in time of low water after the recession of the main body of water. This classification has an important bearing upon the economic features of the country, as it enables us to trace and classify the origin of the sediments comprising much of the tillable lands of the region.

The drainage of the immediate region under discussion belongs to two principal streams and their confluents namely, the Ouachita and the Red rivers. When considered in connection with the great systems above described, it will be seen that these streams, although proximate to each other, belong to two widely differing groups, a fact which has much bearing upon the economic portion of our subject, in that it necessitates separate discussions for the widely differing bottom lands of each stream.

The dividing highland between the Ouachita and the Red river systems, is approximately marked by the railroad running from Hope to Nashville. At Hope this divide is about 140 feet above the bed of the Red river at Fulton, and 84 feet above the Ouachita at Arkadelphia. This fact suggests how much deeper the Red river, the older stream, has cut through the soft strata. The longer stream, the Red river, flows approximately east through most of the region, but upon emerging from the comparatively firmer sediments of the cretaceous, it immediately deflects southward into Louisiana and changes greatly in character. Its bottom lands, notably the most pro-

ductive in the southwest, owing to the meanderings of the stream, occupy a very wide area.

Its principal confluent in Arkansas is the Little river, a beautiful and picturesque stream, which has its origin in the harder strata of the mountainous country of the Indian Territory, and attains considerable size before it reaches the Arkansas line near the village of Cerro Gordo, where it emerges from a rocky canyon. It resembles the upper Ouachita in its sediment, and in the time and conditions of its rises and overflows. Its general direction in Arkansas is southeast. The West Saline the Cossatot and the Rolling fork are large southward flowing tributaries of Little river, having characteristics in common. All the Red river system, and the Little Missouri of the Ouachita system, drain large areas of limestone, green-sand and gypsum deposits, which add greatly to the fertility of their bottom lands.

The Ouachita Drainage.—The Ouachita drainage occupies about a third of the area under consideration. At the southeastern point of Clark county the main stream is formed by the union of the Ouachita and the Little Missouri. These are both local in their origin, and are similar in general appearance above the point of their union. The upper Ouachita, however, does not traverse mesozoic strata lower than the uppermost cretaceous, but flows for many miles through the mountainous paleozoic region, while the Little Missouri, on the contrary, has most of its course in the rich gypsiferous, glauconite and calcareous strata of both the lower and the upper mesozoics, especially those described later as the Trinity division. The bottom lands of the former, above the union, are consequently somewhat sterile, ranking second to those of Red river. Both the Ouachita and the Little Missouri have a principal tributary from the mountain region, the Antoine and the Caddo, respectively, and also from the purely mesozoic area, the Terre Noir and the Deciper.

The upper Ouachita illustrates nearly all the rivers which have their origin in the disturbed region west of the military road, such as the Cossatot, the West Saline, the Little Mis-

souri and Little river. In the paleozoic area it has comparatively little flood plain, but rocky bluffs and shores. Upon reaching the softer and later strata at the mouth of the De Roche it immediately begins to have a less stable channel. There is also a marked physical difference in it after its union with the Little Missouri. Above that stream its waters are clearer, and its channel, although by no means permanent, is comparatively stable. This fact is specially emphasized by the fewer number of "snags," or fallen trees, and these few have usually been transported some distance before reaching their present locations. There are but few outcrops of strata along the channel of the river from the mouth of Bayou de Roche to the Little Missouri, and five out of seven of these are on the south or right bank. The intermittent flood plain or region subject to overflow at the highest waters in the memory of man, is very extensive, averaging five miles in width, while the annual flood plain, or bottom, although varying greatly, averages about one-third of that width. North of Arkadelphia this flood plain is entirely on the east side of the river, excepting very small tracts at the mouths of creeks, the high bluffs being upon the west; while south of that place the flood plain is on the west side, and so continues until the high bluff, beginning at the mouth of the Deciper, again deflects it to the east bank. These flood plains or bottoms are composed entirely of derived soils, clays and gravels, all remnants of old river deposits, such as may be seen in process of formation to-day. The immediate banks of the river, ordinarily from fifteen to twenty feet high, are usually composed of these sediments. The entire plain is covered with forest growth, while great "brakes" of cane are often found in the lowest places. The character and origin of these soils will be discussed elsewhere.

The present bed of the river, as well as the channels which were occupied in not very remote times, are filled with siliceous gravel and cobbles, the transported remnants of the gravel plateau. Near the mountain region this debris is made up of large fragments, but these fragments gradually decrease in

size down streams until they almost or quite disappear in the eastern part of the State. Near the edge of the hilly country the streams have in their beds many angular fragments of "mountain rock" (brown sandstone or quartzite), but these are usually much worn or comminuted after traveling a short distance. But little of the gravel is derived directly from the disintegration of the older rocks of the hilly country, most of it coming from the denudation of the old gravel plateau. The fall line of these rivers is not so easily determinable as that of the streams of the Atlantic states, for the extremes of low and high water are greater than in that part of the country, while the coastal slope is much more gradual, so that there are no precipitate falls or rapids to mark a sudden transition. The floods are sudden, periodic and voluminous, so that streams usually easily fordable are quickly converted into great rivers miles in width, and at highest water from twenty to forty feet deep. In summer these same streams become almost dry.

The Little Missouri is navigable at high water to the mouth of the Antoine; Little river to the Choctaw line, and the Red river to Clarksville, Texas. The head of navigation at low water is from 100 to 300 miles below these points.

The valleys of the drainage system vary with the structure of the geologic formations traversed. In general, they consist of long and gentle slopes from the scarp of the gravel plateau constituting the drainage divides, to within a few miles of their axial streams, interrupted by one or more terraces and plains. There are only a few abrupt bluffs and heights, the principal ones being the high bluff of the Ouachita at Arkadelphia, the Nacotoch, the gypsum bluffs of the Little Missouri near Bierne and Murfreesboro, respectively; the white cliffs of Little river, four miles south of Brownstown. From each of these can be obtained a view of many miles across the bottoms, from which the bluffs have gradually receded as they have been worn away by the currents.

The Flood Plains or Bottoms.—For the purpose of economic discussion the flood plains are classified in this paper as *annual* and *intermittent*, each having certain marked characteristics.

The annual flood plains or bottoms are distinguished by the growth of cane, the water mark upon the trees, the thin deposits of river mud upon the surface, and by numerous sloughs and "cut-offs." The intermittent flood plains are not clearly distinguishable from either the annual bottoms between them and the channel, or the uplands which are not now subject to overflow. The tradition of localities where the "high rises" are remembered by the inhabitants are the only data for this differentiation. The annual flood plain may recede or encroach upon the intermittent, and the intermittent flood plains may encroach upon the dry lands, but the development of the flood plains in general is in the direction of the bluff on the opposite bank of the river.

The width of the bottoms also depends upon the resistance of the materials forming the banks, hence it is that the brooks of the gravel plateau are narrow, clear, and without perceptible flood plains, while those of the cretaceous area of more friable materials are all comparatively wide, though not nearly so wide as where the streams flow through the tertiary. The transition from the soft cretaceous sediments to the softer shales of the Camden series of the tertiary is readily noticeable, the bends becoming more and more frequent, and the banks more unstable in the latter. The age of a channel, too, has much to do with its width.

All the larger streams through the gravel region exhibit in places well marked terraces. This is especially noticeable along the south side of the Little Missouri, east and west of the gypsum bluff, where an old terrace occurs 100 feet above the present waters. Again, in the descent to Messer's creek, north of Centre Point, there is a well defined gravel covered bench some fifty feet below the scarp of the plateau, upon which Dr. Cannon's house is situated. The top of the white cliffs of Little river, and the gravel covered area upon which Col. D. B. Coulter's house is situated are also upon a bench of the Little river. In the valleys of the Cossatot, Saline and Little river there are similar benches, some of which are locally known as "frog levels." These are all at approximately

the same level, but until a topographic map of this region is constructed no trustworthy generalizations can be made.

It is worthy of note and of further study that in altitude and character of the material these benches correspond with that of the smaller gravel of the Prairie d'Ane division, while the hummocks which characterize the Prairie d'Ane occur also upon some of these benches.

The principal streams either transect at right angles the strike of the different geologic formations, as the Saline, Cos-satot, Rolling fork, etc., or follow their partings, as in the case of the Ouachita from Rockport to DeRoche, and of the Muddy fork of the Little Missouri.

The direction of most of the streams depends upon the formation through which they flow, while streams of the same order have the same direction in the same formation. Certain recent geologic changes have also much bearing upon their direction, as will be shown later.

In general, there are two principal directions in which the streams of the region flow: From the west to the east, and from the north to the south. Many of the larger streams, as Red, Little Red, and the Ouachita, have each of these directions at particular portions of their courses. If a geologic and hydrographic map be examined, there will be found a well defined strip of country, narrowing to the westward, from the mouth of the Sabine and Mississippi rivers to the Pan Handle of Texas, in which all the streams flow southward. There is only one logical explanation of this, and that is that the direction of the slope of the country has changed in recent geologic times, and that the valley of the Red river represents an embayment of the Gulf of Mexico, comparable in quaternary features to that of the Mississippi, between Missouri and Arkansas, and Illinois, Kentucky and Tennessee. This will be more fully seen after an examination of the geologic evidence.

The sloping plateau of the Red river embayment, the mountains against which it rests, the drainage system which is destroying it, and the yielding and disintegrating character of the formations which underlie it having been explained, the

general topography is more readily comprehended. In the region near the mountain line the surface is comparatively broken, consisting of high flat-topped gravel divides, the river bottoms are narrow, and the streams intermittent, turbulent and unnavigable. In the region of the main body of the great gravel formation, parts of Hempstead, Howard, Pike and Sevier counties, the main streams and the secondary drainage arising along its northern scarp flow southward in the direction of the former slope of the plains, cutting its southern border into a fringe of points abruptly terminated by Little river. The flood plains, or bottoms, of the larger streams, some of them 200 feet below the level of the plateau, are wide and swampy, like those of the lower coastal region to the south and east, and the upper slopes of the valleys are terraced. In the last mentioned region the divides become broader and less conspicuous, the slopes more gradual, and the elevations, in general, less prominent. The wide flood plains with cypress ponds and "lakes" instead of the ridges, now become the most conspicuous features of the landscape, the streams are more placid, constant in flow, and are navigable in time of mean high water. The region as a whole is marked by the infrequency of abrupt scarps, or other sharp features, such as would be present if there was a consolidated substructure, as in the plateau or mountain region, by broad flood plains and wide meanders of the streams, and by dense forests of pine and hardwood. The population is sparse in some areas, and comparatively thick in others, adapting itself, as will be shown later, to the agricultural capabilities of the underlying geologic formations. In general, however, there are few people in proportion to the great number which the region is capable of supporting, and consequently there is but little alteration attributable to human agency.

A dense forest growth, sometimes of pine and hardwood, and sometimes of hardwood alone, covers the whole surface of the country, except a few bare glades, the whole of which do not aggregate 5000 acres. These bare spots, with the exception of Prairie d'Ane, at Prescott, and Bois d'Arc Prairie, in

southern Hempstead county, and Prairie de Roan at Hope, are seldom of any considerable extent, and are scarcely worthy of the name of prairies, for the true meaning of the word prairie not only implies absence of forest growth, but also great extent.

These are the most obvious surface characteristics, but the essential features of the region can be understood only after a careful investigation of its stratigraphy. This is also largely true of the origin and explanation of all the phenomena indicated in this chapter.

CHAPTER III.

FUNDAMENTAL STRATIGRAPHY.

The underlying rocks of the region north and west of the Fort Towson road in Arkansas are paleozoic, while those of the region east of it, and to which the further remarks of this paper will be confined entirely, consist of the uppermost jurassic, cretaceous, tertiary, and quaternary strata, collectively termed the neozoic.

That portion of the neozoic included in the triangular area southwest of Arkadelphia, bounded by the mountainous country on the north, and the Iron Mountain railway on the southeast, has been the special object of the writer's attention, although remarks are frequently made regarding the adjacent territory. South of Arkadelphia the Iron Mountain railway approximately divides the neozoic region into two principal geologic areas, the western of which is much broken and composed of a diversity of formations (the interior hilly country of the topographic classification), while to the east, the country is approximately level and devoid of mesozoic and paleozoic strata, being composed entirely of tertiary and post-tertiary sediments.

The line of demarkation between the cretaceous and the paleozoic, although generally concealed by the overlying quaternary, is, in places sharply defined; this is not always the case with the quaternary, tertiary, and cretaceous terranes, owing to the ready disintegration of their unconsolidated sediments, even though the stratigraphic breaks between them are often clearly defined. It is therefore often impossible to trace the partings between them, and for this reason such lines are sometimes lacking in sharpness upon the map, and either formation may cross them, the tertiary often extending westward up the watersheds and the cretaceous eastward in the

valleys, while the post-tertiary is distributed almost everywhere over both of them.

The stratigraphy of the whole neo-zoic area may be defined as follows :

1st. A substructure of unstable, friable, soluble, marine sediments, such as chalks, clays, and sands, deposited horizontally and at present unaltered other than by occasional cementation from lixiviation, solution, and redeposition of its own solubles. This process causes radical changes in the appearance of the terranes before and after exposure to these agencies. The substructure is obscured in most places by its own residual debris, or by the alluvium and transported soils of other formations.

2d. The debris, which is the result of the disintegration of the substructure in situ, or the recognizable surface debris of the substrata of other regions that has been removed from its original place and redeposited. To the last named class belong much of the gravels, the soils, and the alluvial deposits of the river bottoms. No true lacustral fresh water stratified deposits have thus far been identified in this region.

The mountains to the west and north, upon which the neo-zoic area borders, were the ancient continental shore line of the several marine invasions, and against it were deposited, in oceanic waters, the various sediments which now form the substructure of the region under discussion.

These outlines were also probably the antecedents of those of our present Gulf of Mexico, but there is no evidence known of the Gulf's waters having gradually receded to their present outline, as it is popularly supposed, nor that all the sediments from its most ancient outline to its present, are simply the result of continuous but frequently and slightly interrupted succession, so that in going inland from the coast the successively older strata are met. On the contrary there is evidence that the neo-zoic area has been the scene of many alternate inundations and denudations, and that the age of its sediments is not always proportionate to the distance from the coast.

The atmospheric agencies, such as are now seen in operation around us—the rain, heat, cold, winds, and moisture—have been the most important factors in carving out the present surface features. Post-tertiary aqueous action, however, has also played a most important part in eroding the greatest irregularities of surface.

It is then by meteorological and chemical agencies, both organic and inorganic, that the surface has reached its present agricultural conditions. It is also by the study of the laws that control surface phenomena, together with the chemical and mechanical conditions of the substrata, that we must find the causes of the sterility and fertility of the earth's crust, and learn how, by artificial modification, we can adapt them to our industrial or agricultural needs, and how we can secure the greatest, surest, and most lasting returns. (See part on economic geology.)

Although the order of deposition of the substructure is simple, that order is so obscured that it is not readily apparent to the ordinary observer. In some places the substructure has been removed, while in others it has been concealed by successive denudations and depositions. Moreover, the material of this structure presents a great variety of appearances under different conditions of exposure, so that its extent, thickness, etc., are not readily apparent. The untilled soils resulting from the weathering of all the strata have a homogeneous appearance and an absence of individuality that fail to indicate their origin. The forest growth also obscures most of the substructure. There are no bold and projecting exposures of bed rock, such as occur in the mountainous paleozoic regions interior of the coastal plain, and even the deep excavations of the numerous streams, on account of the unconsolidated character of the strata previously alluded to, have the original substructure exposed at but few points. In fact, were it not for the cultivated fields, and newly dug wells throughout the region, it is doubtful whether even the facts here presented would be ascertainable.

Another result of the unconsolidated strata of the neozoic addition is the absence of conspicuous partings. In the older continental area, upon which nearly all American geologic observations and accepted geologic methods have been based, the hardness and constancy of the formations are such that sharp lines of demarkation are readily and accurately traceable between them, but this is more difficult in the neozoic region, and it will be many years before they can be more than approximately determined. The surface exposures of the neozoic deposits of the timber covered region of the South have a homogeneous appearance, so that one may ride over them for days and months without learning to distinguish the underlying formations. There are some differences, however, but they have not been reduced to any law that would render it possible to differentiate them; in fact, since there are usually no sharp lines of demarkation or interruption in the deposition of these sediments, and no marked change in their composition, but gradual transitions from clays to sands, and vice versa, there can be no sharp lines of surface demarkation. Here the geologist not only meets the ordinary problems of dip, extent, etc., but is confronted with a duality of appearance of strata, before and after atmospheric exposure, not common in older geologic regions.

The writer has been able to recognize the horizons, or members named in the subsequent chapter, whereby their discussion may be rendered intelligible. The nomenclature is local and provisional, and only intended for the area under discussion.

CHAPTER IV.

FORMATIONS OF THE POST-TERTIARY.

All the region under discussion bears evidence of one or more comparatively recent marine inundations. These inundations partially leveled many of the former irregularities of surface, wore away the underlying paleozoic, cretaceous, and tertiary strata and spread over them masses of gravel debris, the most conspicuous of which now remaining are still visible over the great plateaus of Howard and adjacent counties. It is only where the post-tertiary formations have been worn through and carried away, that we can see the underlying mesozoic and tertiary strata. The correct interpretation of these post-tertiary formations is a labor of years that will involve long and tedious investigation, not only in Arkansas, Indian Territory, Texas and Kansas, but east of the Mississippi, and the writer must of necessity disavow any attempt at the final interpretation of their associated phenomena. Neither is it possible at this writing to predicate the exact age and methods of the deposition of these formations, or to correlate them with similar or synchronous ones in other regions.

There is little evidence so far, except lithologic and hypsometric dissimilarity, that all these post-tertiary beds are not different phases of the same formation. Most vigorous search upon the writer's part has failed to develop any demarkation or to prove continuity between them. But it must be remembered that there is almost no opportunity for favorable exposures of such contracts in the heavily timbered region of southwestern Arkansas. Until some investigator with capital, time and experience, makes a careful study of the whole cotton belt, no classification or correlation can be regarded as more than a temporary expedient. That these beds are post-tertiary, is shown by their position above the terranes of the tertiary. That they are not post-quadernary is attested by the

entire absence of the remains of the mastodon, which occur in such great quantities, both in the more recent superimposed coastward formations of Louisiana and Texas, and in the numerous alluvial and detrital deposits of western and northwestern Texas. Nowhere in this portion of Arkansas has the occurrence of these characteristic post-glacial remains been reported. They occur in the denuded area of Texas to the southward and westward from Mobeetie in the Pan Handle as far as El Paso, Eagle Pass and other points on the Rio Grande, all along the lower coast country, and at Dallas, Denison and Austin on the Wichita river, and at numerous intermediate localities.* These remains always occur in detrital deposits.

In general it may be said that all of the post-tertiary formations, except, perhaps the sands, show in their sediments that they were derived from the breaking down of the older formations which lie interior of them, and in some respects indicate that they are the records of slow and comparatively moderate subsidences.

For the present purposes these deposits are divided into the following beds, some of which may rank as distinct formations.

1. The Red river loess (?) and alluvium division.
2. The white clay and gravel till, or Prairie de Roan division.
3. The plateau gravel, or Centre Point division.

1. *The Red River Loess.*—In the northern edge of the town of Fulton on the Red river can be seen a typical exposure of the Red river loess formation, consisting of an intensely red loam, approximating in color to the present red sediments of the river. This formation is found some fifty feet above present high water mark, and extends inland, often several miles from the present stream. These deposits continue far into Louisiana on the southeast, and west of Denison in Texas. In general appearance this loess is difficult to distinguish from the residual debris of the Camden series and from the other arenaceous, post-cretaceous and cretaceous formations of the South, and

*I am indebted to Rev. W. F. Cummins, of Dallas, Texas, and to Mr. E. T. Dumble, of Houston, Texas, for some of these localities.

the writer will not attempt at present to differentiate it from them.

Deposits of similar appearance are reported from the Atchalafaya of Louisiana, and they have been traced to near the Wichita Mountains, near the one hundredth meridian in Texas, principally upon the northern side of the river. Hilgard has shown the occurrence of this formation in northern Louisiana,* and has estimated that it continues as far up the river as Shreveport. The writer has seen the continuity of the deposit far west of Denison, Texas, however, at which place it was first described by G. G. Shumard as follows:† "The Loess formation, whose existence in Texas was first published by myself in 1852 (See Marcy's Report) is largely developed in Grayson county. It is usually exposed in the form of vertical cliffs along the different streams, and here attains a general thickness of forty or fifty feet. The best exposures of this formation in the county are met with along the banks of Red River, and Post Oak, Choctaw, and Big Mineral creeks, where good vertical sections of it, thirty or forty feet in thickness, are frequently exhibited. Whenever examined it has been found reposing upon beds of pebbles, and the line of division between the two is by no means distinct, the one formation gradually running into the other." Mr. Shumard, however, confused this with another formation which "is here composed of highly indurated, compact, siliceous and calcareo-siliceous clay," and where it is "exposed along Red river is made up of alternating bands of marly clay and fine siliceous sand, and is usually deeply colored with red oxide of iron." The "loess" occurring in the interior of the county is upon the other hand "usually much less ferruginous, of a light yellow color, and homogeneous in character. Not unfrequently it contains small rounded pebbles of white carbonate of lime, and siliceous rocks, and is sometimes, especially towards its up-

*Supplementary and Final Report of a Geological Reconnoissance of the State of Louisiana, 1873; pp. 26-27.

†A Partial Report on the Geology of Western Texas, by George G. Shumard, Austin, 1886; pp. 126-127.

per portion, thickly marked with decayed roots of vegetables." Mr. Shumard also states that "this formation is rich in organic remains, consisting mainly of terrestrial and fluviatile shells. These shells are quite numerous, are generally in a good state of preservation, and are equally distributed through every portion of the formation. Fragments of fossil wood and decayed bones are also sometimes met with in this formation," but the writer has failed thus far to find any organic remains, except some mastodon bones at Denison, which were said to have come from this horizon.

The correctness of Mr. Shumard's interpretation of this Red river loess may perhaps be questioned, owing to the complexity and similarity in the vicinity of Denison of the arenaceous formations of the cretaceous, tertiary and quaternary age, all of which have great resemblance to each other. The writer has differentiated and traced the Denison quaternary beds from the Red river northward for fifty miles to the mountain line, where they are found covering the cretaceous formations. The only fossils found were remains of the land shells which now inhabit the surface of the region. This formation is homogeneous throughout, and has more the appearance of estuarian than that of a mere river loess.

In the region last mentioned the sand is without the laminated structure found in the Camden (tertiary) series, but is white beneath, and red upon the surface, with occasional patches of siliceous gravel, especially near the mountains.

While this loess-like deposit extends so far to the north of Red river in the Indian territory, it is remarkable that it seldom reaches more than two or three miles south of the river on the Texas side, until the Arkansas line is passed. Mr. T. V. Munson, of Denison, Texas, has advanced a theory that Red river, in the portion of its course adjacent to that town, flows in a great east and west fault of the older cretaceous rocks—a theory which the writer has not been able either to prove or disprove, and which is here presented without other comment than that, if such is the case, it may likewise explain the genesis of the Red river embayment. The apparent northern

limit of the quaternary sands in the Indian Territory is the Ouachita mountain system. The writer has not found these sands north of Stringtown, or of Ardmore upon any of the mountains of the region, but it is probable that they may extend much farther in that direction, where the mountains are more nearly destroyed, as at the Arbuckle-Wichita gap in the Ouachita system. These sands, over a hundred feet in thickness, are also beautifully displayed in the cuts of the railway between Ardmore and Red river, along the line of the Santa Fe railway. Their limit west of the Santa Fe railway has not been traced, but they continue for a long distance in that direction, where they have been noted in one or two localities by Shumard.

It is evident from the character of the great trough, some fifty miles wide, in which this loam is deposited, and from the denuded condition of the adjacent highlands in Texas, that these sands are deposited in an old channel carved out before their deposition. These facts, together with the topographic configuration and character of the "lakes" of Red river immediately east of the region discussed in this paper, justified Dr. Hilgard in remarking that to that point "the valley of the Red river, like that of the Mississippi, was converted into an estuary at the time of the Champlain depression." Without regard to the exact time, the writer not only believes in the tertiary and post-tertiary estuarine indentation of Red river as far up as Shreveport, but that it extended many hundreds of miles west, up the broad valley south of the mountain system of Southern Arkansas and Indian Territory nearly to the one hundredth meridian.

Prairie d'Ane or White Clay Till.—The Iron Mountain railway from south of Arkadelphia, Clark county, to a few miles north of the town of Fulton, Hempstead county, transects a number of drainage divides, the summits and upper slopes of which are composed of unstratified white or yellowish clays, sometimes mixed with siliceous gravel, sparsely imbedded in places, and in others constituting well defined hummocks some fifteen feet in mean diameter. Occasionally small concretions

of oxide of iron occur. Where the gravel is more plentiful, the surface becomes glade-like or devoid of timber growth. Some of the glades or prairies attain considerable extent, such as Prairie d'Ane at Prescott, Prairie de Roan at Hope, and Bois d'Arc Prairie ten miles south of Washington. At other places the formation is marked by an exclusive growth of sweet gum (*Liquidamber styraciflua* L.), or of post oak (*Quercus obtusiloba*), an exclusiveness indicative of a disproportion in the fertile ingredients of the soil. *The character of these beds varies with the character of the formation which underlies and is immediately adjacent to it on the west.* Where the Arkadelphia shales underlie these beds to the westward, as at Gurdon and south of Gum Springs, they consist of the debris of the clays; when the arenaceous high bluff sands underlie it, the till is sandy and almost indistinguishable from them, as east of Washington; and if the chalky cretaceous marls underlie them, the till is often of the character of the "black lands"—being almost a pseudomorph of the conditions of that residual cretaceous formation. The westward border of this formation has been traced with approximate accuracy, as laid down upon the map, extending westward to the Marlbrook-Columbus ridge, the divide of the Ozan and Red river drainage. Its thickness could not have been great, for the underlying cretaceous and tertiary strata outcrop in many places near the general surface level.

The best exposure of this formation can be seen along the lower public road leading from Washington to Hope, which transects the series, and along which the following formations can be seen as one goes westward:

1. *White Prairie d'Ane clay*, with occasional gravels, mostly angular, white without and red within. Many small fragments of lignitized vegetal matter occur in this formation from Hope to a point four miles west of there, and on ridges still farther west.

2. *Carrigan black lands*, similar to the Okolona black lands, but differing from them in that they are transported soils covered by gravel, and filled with gravelly debris.

3. *White argillaceous sands*, ferruginating to a deep orange red, as at Washington, west of Gurdon, at Rome, at McCauley's divide in Clark county, and at other places. The sands are in part the residuum of the underlying cretaceous.

4. *Stratum of jaspery gravel*, composed of small jasper and other quartzitic gravels of the average size of a hen's egg, with a few pebbles of white quartz, seen on both sides of Town creek bottom near Washington. There are two strata of this material alternating with sands, and resting directly upon the cretaceous sands.

5. *Band of small white quartz pebbles* not exceeding an inch in diameter. Total thickness of bed five feet.

6. *The greensand beds of the cretaceous*, seen in the town of Washington, on Main street, opposite the Eakin place.

This Prairie d'Ane division is difficult to distinguish, though it is undoubtedly separated from the Bingen sands and plateau gravel. In general, however, it is void of the lamination characteristic of the Camden series and Bingen sands, and its gravels are smaller, more angular, and usually whiter exteriorly than those of the plateau region. Neither are the soils so red from ferrugination as the plateau region. The presence of silicified wood, and of large fragments of "mountain rock," especially distinguish this debris.

The hummocks or mounds, which mark this formation in many places, are usually fifteen feet in diameter, and are often mistaken for Indian mounds. These hummocks are so numerous and uniform, and so extensive, occurring all through southwestern Louisiana, southeastern Texas, and Arkansas, that the question of their artificial origin is unworthy of consideration.

This formation covers much of Arkansas, especially adjacent to the Iron Mountain railway. The surface of eastern Clark, Nevada and Hempstead counties, and nearly all of Little River county, is covered by it. It also characterizes much of the region of eastern Texas, north of the Texas Pacific railway, while its prairies and hummocks are seen along the entire distance from Texarkana, on the Transcontinental division of the Texas Pacific railway, as far west as Blossom Prairie in the

eastern edge of Lamar county. Frequently the gravel and clays are washed away, revealing the Rocky Comfort chalk, and emphasizing the nonconformity of these two formations. The prairies at New Boston and elsewhere are of this character, and not of cretaceous age. The prairies of eastern Arkansas, along the St. Louis, Arkansas and Texas railway, also have a slight resemblance to these beds, sufficiently striking to call for a close investigation and comparison.

The Plateau Gravel.—Rounded and flattened cobblestones and gravel occur on all the high ground in the territory under discussion, either in beds or as individual fragments. The material is of the same siliceous character as, and indistinguishable from, the gravel now found in the river beds. This material is composed of the upland gravel, and is also derived from the fractured and weathering siliceous strata of the paleozoic region west of the military road. It occurs as scattered and single specimens, or as great masses on both the residuary and derived soils, accompanied or unaccompanied by any finer sediments of the same origin. Both the size of the material and the quantity of deposits increases as the hilly country is approached. All the high country along the Fort Towson military road is composed of this drift, which, in places, must be forty or fifty feet deep. In general this formation includes the red gravels and clays, forming the uplands of the northern half of the interior margin of the region, becoming more and more conspicuous to the westward toward the Choctaw line, and attaining its greatest development in the central portions of Howard, Pike, and in northern Hempstead counties. It is the material of the plateau constituting the ancient beach or base level described in chapter I, which once abutted against the mountain country. The sediments of this marine inundation present two chief characteristics in this region, appearing either as:

First, a stratified deposit of coarse gravelly soil, occupying an ancient level now seen only on the high, flat divides of streams; or,

Second, as the debris of the first, which has been transported and redistributed over the terraces and lowlands by recent aqueous agencies. These two phases are often quite difficult to distinguish.

The general geology and extent of this formation over the rest of the State of Arkansas, and its relation to similar deposits along the North Atlantic coast are being studied and will be discussed by the State Geologist when sufficient data shall have been collected. It is sufficient here to say that it is the most important factor of the region, and that it once covered continuously every foot of it, and reached far beyond its borders on every side, and it is only through its history and relations that the underlying formations can be understood. The destructive erosion of the system of streams which drain this region of the plateau gravels, however, and perhaps other ancient channels, have long since cut it into isolated fragments, and often removed it entirely, so that now, in general, it is found in isolated and approximately flat-topped hills occupying the high divides between the principal streams, and at an altitude generally exceeding 400 feet above the sea. It occupies all the high divides of Red and Little rivers in Little River county, extends into Arkansas from the Indian Territory, and abuts against the south bank of Little river at Cerro Gordo. In Sevier county it is a narrow plateau forming the dividing ridges of the Cossatot and Rolling fork, and of the Saline and Cossatot. By reference to the map it will be seen that the most extensive area of this formation in the region under discussion is the great plateau of middle Clark, Pike, Howard, Sevier, and northern Hempstead counties. This area is east of the West Saline, south of the Messer's creek, Rolling fork, and the Little Missouri, north of the north fork of the Ozan and west of Mine creek. East of the Little Missouri in Clark county, and the Ozan in Hempstead county, the remnants of the plateau are very limited, and show in places on the divide of the Terre Noir and Big Deciper, Clark county, south of the Boseman plantation, and the Terre Noir-Little Missouri divide in the vicinity of Dobyville, and along the military road from

Antoine to the mouth of the Caddo near Arkadelphia, and is probably identical with the gravel plateau east of the Ouachita basin, seen in the vicinity of Dove Park Post-office. Nearly everywhere it covers the paleozoic parting, extending far over the paleozoic area.

The surface features of the plateau gravel formation group themselves in two classes. The first is characterized by gently undulating and extensive areas of gravel, accompanied by sufficient ferruginous clay and finer material to make a good agricultural soil. These occupy the higher water sheds, and are covered by a hard wood growth of timber, as seen in the great plateau country. The second class is characterized by sharply undulating red, sandy, clay lands, outcropping beneath the deeply rounded red sandy lands upon the southeastern margin, and constituting the immediate slopes of its principal streams. These are especially conspicuous in southern Howard and Sevier counties, and northern Hempstead, and skirt the southern margin of the gravels.

Although not so rich as many of the residuary soils of the other formations, the upland gravel lands have, with the exception of the cretaceous black lands, always been the most densely populated portion of the region, and even upon its borders where plantations are located upon the lower bottoms or black lands, their proprietors build their residences upon the red lands. This is due to two principal reasons: first, to their superior elevation and freedom from the malarial influences of the lowlands; secondly, purer and more wholesome water, less contaminated by obnoxious minerals, can always be obtained in the porous gravel. Then, again, while these soils are not preponderatingly rich in some one fertile ingredient, they are better drained, are good all-around producers, and are capable of great productive possibilities, as is shown in the agricultural portion of this work.

The individual gravels, cobbles and pebbles of this formation are always composed of much rounded and often flattened, dark colored, red, gray, brown, yellow, black, or blue novaculites, and quartzites of great hardness. In places these are

cemented by a hard ferruginous matrix into extensive and massive beds of conglomerate. The white quartz pebbles which occur so abundantly at the base of the Prairie d'Ane division do not make so large a proportion of this formation. Occasionally vast areas of gravel are almost pure white in external appearance, owing to the deoxidation by forest fires, or rarely, to saline excrescences. Upon being fractured, however, they show their original color.

This gravel is seen in place everywhere over the great plateau above mentioned, but the best exposures are at Centre Point in Howard county, at Brocktown in Pike county, and in the banks of Wolf creek, and near Wolf Creek Post-office in Pike county.

The gravel composing the surface of the great plateau near its northern scarp, and the detached fragments of this plateau covering the mountain rock in places north of the neozoic area are very large, often exceed six inches in diameter, and are sometimes too heavy to be conveniently lifted with the hand. Occasional pieces of the adjacent "mountain rock" occur among the gravel, the great mass of which is composed of material brought from a greater distance.

Often the cobbles are smooth and flattened oval discs, resembling those made by wave and tidal grinding. The intense ferrugination and the absence from this formation of silicified wood which occurs so extensively in other formations farther to the east is a prominent characteristic. No fossils of any kind whatever have, as yet, been found in these beds.

The transported debris, as well as the gravel in place, always decreases in size and quantity coastward from the mountain region. The more sandy beds of this formation are not readily distinguishable at first glance, even by the geologist, from the yellow Trinity sands, or the residual red clays and sands of the Camden series, owing to the fact that even their microscopic differences are but slight. In general, however, they are coarse grained ferruginous sands or flocculent clays, or both, irregularly bedded, unfossiliferous, and devoid of green-sand, mica, or any considerable quantity of calcareous matter.

In many places, as at Centre Point, Temperanceville, and elsewhere, the layers have a coarse mealy structure, and are largely composed of clays which, when sun-dried, can be used after the manner of adobes. The structure of these clays is strongly indicative of their being the decomposed remnant of granitic debris which could not survive the grinding and oxidation of the harder gravel. There are often coarse grained masses of ironstone resulting from the oxidation of the contained iron, and its deposition in the interstices of the porous sands. These ferruginous masses are sometimes spherical, sometimes angular, resembling broken fragments of castings, whence they take the local name of "iron pots." They are either of an intense orange or blood red color.

This sand and gravel of the plateau gravel occurs above the Arkadelphia shales at Arkadelphia, Clark county, and at the Boseman place south of the Big Deciper, where it rests upon the *Exogyra costata* clays. It occupies the scarp of the Missouri flood plain on the Pike county side, at the crossing of the old military road, while sixteen miles southeast of Nashville in the creek bluff north of the railway, there is a perpendicular exposure of twenty-five feet of these sands. In the creek at Centre Point it can be seen alternating with the gravel, as well as at numerous places in the slopes of the Saline in Sevier and Howard counties. Four miles south of Nashville it constitutes a firm sand-rock bluff in Mine creek. The numerous hills on the road leading from the Salt Wells ford of the Saline to Nashville are all of this sand. It also outcrops along the base of the Messer's creek escarpment. The transported debris of this plateau is found nearly everywhere. It often occurs both upon the high points of the upper cretaceous, and in the valleys, in varying sizes and quantities; sometimes but a few specimens are found, and again the beds of the rivers are entirely composed of it, forming bars twenty feet in depth and many acres in extent. The quantity and wide distribution of the gravel of this formation are most remarkable, as well as its uniformity, especially along the paleo-neozoic parting.

The partial thickness of the original plateau gravel formation at Centre Point, measured at the face of the great escarpment (see general section No. 2), where it shows the least evidence of denudation, is seventy-five feet. This is only fractional, and I estimate that it must be fully 200 feet at the Jordan Reese place, one mile south of Centre Point. Between Wolf creek and Brocktown Post-office in Pike county, there is a great body of this plateau gravel, where its features can best be seen and appreciated.

The average altitude above tide of the present surface of the great gravel plateau at Ben Lomond, Howard county, at Centre Point, near its northern edge, and at the Choctaw line near Cerro Gordo, is about 550 feet, as estimated by combined railway levels and barometric measurements.

The general slope of the original surface of this gravel deposit was and still is southward from the mountain region, as attested by the dip of its stratified beds, exposed at numerous favorable points at Centre Point, and by the direction of its drainage system, which follows the slope. The Rolling fork, the Cossatot, the West Saline and Mine creek, the streams of greater magnitude, all illustrate this principle in the plateau, while it is still further exemplified by the minor drainage of the isolated remnants as seen at High Bluff near Arkadelphia, and the Plaster Bluff near Murfreesboro and at other points where the secondary drainage at the very brink of an entirely different arterial stream flows southward away from it and in a direction at right angles to it. This southward slope continues on the north side of Red river as one proceeds westward through the Indian Territory and Texas. This same feature is also shown in the subsidiary ravines of the Terre Rouge, the Ozan and the Terre Noir.

A conspicuous result of the southward drainage of the Howard county plateau is the fringing, or serration, of its southern border, and the increased areas of the underlying red land consequent upon the removal of the overlying gravel and the widening of the basins. Traveling westward, a few miles south of and parallel with the northern scarp of this

plateau, the surface is made up mostly of wide, flat, gravel-covered divides, the basal clays never appearing except in limited areas in transecting the valleys. A line drawn a dozen miles south of this, say between townships nine and ten, would cross great areas of red land, while the gravel would either occupy comparatively narrow areas along the highest divides or be absent entirely, as can be seen upon the map. The red land areas from which the gravel has been removed are characterized by highly arched divides, instead of flat-topped ones.

The homogeneity of this great stratified gravel deposit throughout its extent, its uniform occurrence in certain limits above sea level, the uniformity and hardness, and the flattened discoidal shape of the material of which it is composed, and its stratification, all clearly show that in origin it could have only been the near shore debris of a great body of water, which covered the country at a comparatively recent geologic period. The great size of the gravel and cobble adjacent to the military road shows that the resisting shore line could not have been remote, while the range of mountains to the northward is probably the source of the debris and the remnant of the old shore line against which the oceanic waters beat, and from the south side of which it was taken. It is also evident that this shore line was not coincident with the older mesozoic parting, but that it once extended far inland of it, upon the paleozoic mountainous area, and wore away to the northward for twenty miles the paleozoic strata, and also those of the mesozoic that probably extended over them. (See cross sections.) The date and extent of this body of water will be more thoroughly discussed by the State Geologist, and it is only necessary to say here that it occurred long after the deposition of the cretaceous and tertiary formations, and before the Prairie d'Ane and Red river beds had been deposited. Only where this formation has been worn through by streams can we see the underlying ones. At Lewisville, in Miller county, and at numerous other places it overlies beds belonging to the Camden series. At the high bluff of the Ouachita at Arkadelphia it rests upon a horizon of the upper cretaceous; on the

Terre Noir-Deciper divide upon rocks of another series, and at the chalk cliffs of Little river upon those of still another. At Rocky Comfort it rests upon the basal chalk of the upper cretaceous, while at Philadelphia church and Cerro Gordo it rests upon the lower Comanche series. Along the scarp of the great valley it rests upon the Trinity sands and limestones, and to the north upon the paleozoic rocks. In fact it represents an inundation of water in a comparatively recent time, which has leveled and covered all the older underlying formations. No fossil remains have been found in Arkansas in this formation, except a few vegetal traces. Not even silicified wood, nor any organic material of paleontologic value in determining its age has as yet been found in it.

The different altitudes of the base of this formation in the region under discussion, varying from 353 feet at Nashville on its eastern margin, to 550 at Centre Point, near its north-western edge, show that the whole neozoic and paleozoic systems of the region have been elevated at least 700 feet in early post-tertiary times, a fact which has a most important bearing upon the geologic history of the southern and southwestern United States.

CHAPTER V.

GENERAL CONCLUSIONS ON THE QUATERNARY.

While realizing the insufficiency of data concerning the quaternary history of this portion of the United States, the great extent and significance of the deposits of this age are so evident that one can not refrain from a few conclusions. The most impressive fact is that these quaternary deposits represent more than one inundation. The later or Red river and Prairie d'Ane phases resemble in many respects the great quaternary deposits of southern, eastern and northeastern Texas, Louisiana and Mississippi, which have been called the Port Hudson formation, by Hilgard, as well as those of the upper Canadian river. The plateau gravel has its counterpart in the Buttahatchie gravel of Alabama, and perhaps its accompanying but finer sediments in the chocolate loams of the south, or staked plains of Texas. Especially striking is the resemblance collectively to the formations described by Hilgard as the "orange sand," and flat woods deposits of Mississippi, which are probably the inland phase of the Port Hudson. These are described in the "Report on the Geology and Agriculture of the State of Mississippi," pp. 3-46. Nearly every detail of this formation has its counterpart in similar phenomena in Texas, Arkansas and Indian Territory (Choctaw Nation) except where Hilgard includes phenomena in the orange sand, which the writer has preferred to treat as a residual deposit in Arkansas. That these distinct phases also existed in Mississippi, although Dr. Hilgard was cautious in differentiating them, is shown by the following descriptions of the Mississippi gravel, which will be recognized as comparable to the two phases recognized in the Prairie d'Ane and the plateau gravel formations of Arkansas.

After describing minutely the arenaceous divisions of these quaternary beds of Mississippi, Dr. Hilgard says: "The mate-

rial next in frequency of occurrence to the various kinds of sand above mentioned, is pebbles or shingle, either cemented into pudding stone, or, more frequently, loose and commingled with sand and clay. The stratigraphic position of the main pebble stratum appears to be, most generally, below the heavy strata of orange sand proper; it is not infrequently, however, underlain by similar sand deposits, while minor deposits, especially of small pebbles, occur occasionally in the upper strata of the orange sand formation. There are within the State two distinct regions of occurrence in which the material appears in force. One of these extends along the eastern edge of the alluvium of the Mississippi river. * * * *

"The other region of occurrence of the pebble bed begins at the N., on the Tennessee river, in E. Tishomingo, and extends along the waters of Big Bear creek, and to the eastern heads of the Tombigbee, reaching the latter stream by way of Hurricane and Bull Mountain creeks, in Itawamba county. It then extends southward on the eastern side of the Tombigbee, and is continued into Alabama, meeting the great pebble beds of the Warrior, which bear the city of Tuscaloosa. It appears that the pebble beds, as well as the orange sand, in great force are found well developed in the northern counties of Alabama. Great masses of pebbles are being moved southward from these beds, by the Warrior and Tombigbee rivers, whose navigation they tend to obstruct; the materials of the more ancient beds, however, as well as those now being formed by the rivers, become finer as we advance southward, and ultimately mingle, imperceptibly, with the sands of the coast. (Tuomey.)

"Whether or not the two great belts of pebble deposits are connected with one another somewhere in West Tennessee, I have not learned. p. 12. * * * (They are not connected.—R. T. H.)

"As for the material* of the pebbles themselves, it is almost exclusively siliceous; hard aluminous sandstone, or siliceous

*This material differs from that of Arkansas, because the rocks from which it is derived are different.

claystone, is occasionally found, but by far the prevalent material is the several kinds of amorphous quartz-chert, hornstone and jasper, with numerous varieties of the rarer rocks of the same class. (pp. 12-13.) * * * Porphyry and trappean rocks are of a rare occurrence, though not entirely absent. *There is a marked difference of character, however, between the pebbles of the eastern and of the western pebble region.* In the former (at least in the valley of the Upper Tombigbee) chert and hornstone, with siliceous and aluminous sandstone, and some quartzite, are almost exclusively present; while in the western belt, along the Mississippi, a great variety of rocks, as above mentioned, is generally found. In both regions, however, fossils of the ancient paleozoic formations are of frequent occurrence in the pebbles themselves. (p. 13.) * * * The average size of the pebbles might be stated as being between that of a pigeon's and a large hen's or turkey's egg. But the maximum size is found very considerable, and somewhat puzzling to account for, on the supposition of transposition by water alone." (p. 13).

Dr. Hilgard also alludes to the occurrence of erratic boulders of white quartzite in Mississippi, but notes the absence of glacial scratches. The absence of irregular and striated boulders in this formation is especially noteworthy. A few large angular blocks of "mountain rock" have been observed near its interior margin, but these are never far distant from an outcrop of the original bed rock from which it may have been derived. In fact every evidence points to the fact that these sediments are the result of waters having open connection with the present or ancient seas, or of glacial currents, as intimated by Hilgard. It would only be adding more confusion to that which already obstructs every phase of American geology for the writer to make positive correlations of these Arkansas strata with those of Mississippi, but his limited observations upon them certainly tend to prove their identity. The true kaolinitic orange sands along the Memphis and Charleston railway have their counterpart in the Red river sands of Arkansas and of northeastern Texas, and in the Red river sands of southern Indian Territory.

The Prairie d'Ane division of Arkansas and Texas is identical with the flat woods of Mississippi. The gravels, as seen along the eastern margin of the Mississippi beds, have their counterpart in the smaller gravel of Prairie d'Ane east of the plateau. The larger and different Buttahatchie gravels of northwest Mississippi, Alabama, and the Sequatchie valley of Tennessee, are repeated in size, relation to the mountain region, stratigraphic position and altitude by those of the plateau region.

There is also strong resemblance between the two great remnantal ridges composed of cretaceous rocks of Arkansas and Mississippi, the Marlbrook and Pontotoc, respectively, which separate the more ancient plateaux (Buttahatchie and Centre Point regions) from the more recent flatwoods and Prairie d'Ane phases. These peculiar ridges, so symmetrical on each side of the Mississippi, suggest that they are remnants of the later inundations, instead of being of lacustrine origin, as has been popularly supposed. The following remarks of Dr. Hilgard's concerning them in Mississippi are equally applicable to them in Arkansas:

"As to the hypsometrical position of the cretaceous prairies it is not a very definite one. Locally they are surrounded by, and lower than adjoining ridges, but this is by no means the rule. Large bodies, on the contrary, seem rather to occupy the position of dividing plateaux on a level, or nearly so, with the hilltops of adjoining uplands. Their position, no less than their material, seem, therefore, to forbid attributing to them a lacustrine origin; while a comparison of the composition of the prairie under clay and of the rotten limestone will dispose of the idea of 'surface disintegration.' "*"

If the evidence of the distinctness of the plateau gravel and Prairie d'Ane divisions are slight in Arkansas, it is not so in other regions. Perhaps the most important fact in all this region is the deep erosion which the gravel plateau has undergone. This is seen in the deep cut streams and accompanying

*E. W. Hilgard on the Quaternary of Mississippi, American Journal of Science, May, 1866.

terraces, or second bottoms and "frog levels," as they are called. This is also seen in the valley or trough through which the Ultima Thule military road passes, and which has evidently been carved out by some more recent inundation. If this erosion was aqueous, whence and how came the flood of waters that accomplished it? It is evident that it must have come from the west, and that the time must have been either that of the Prairie d'Ane phase or later, as is shown by the hypsometric similarity of the terraces. These terraces and troughs are by no means local and confined to this region, however, for Dr. Hilgard has long since described similar phenomena in the Mississippi,* while all of New Mexico and Texas, especially the valleys of the Pecos, Rio Grande and Canadian benches, and Indian Territory and New Mexico, are replete with examples of these old quaternary valleys, filled with their characteristic sediments, and cut through by the more recent streams.

* "*The Hummocks,*" or *Second Bottoms*.—"While the period marked by the yellow loam and its equivalent must have presented features not now exemplified, called forth by causes which have ceased to act, the formation next in upward order differs from those now in progress only in the quantity or intensity of the action which produced them. The Second Bottoms form part of the valleys of all the larger streams of the State, and in some districts even of the 'creeks.' They are in general most extensive where the material of the adjoining uplands was most easily denuded (without being too pervious, as in the Pine Hills of the south), and has therefore permitted the excavation of wide valleys. Where that material resisted denudation, the contraction of the valley and consequent greater swiftness of the streams have either prevented the formation of these deposits, or caused their subsequent removal. •

"There are two points of difference between these 'second bottoms' and the 'first bottoms' of the present era, which enable the observer to distinguish them even when either is entirely absent. In the first place 'the hummock' is always out of reach of the highest water within the memory of the 'oldest inhabitant,' and in many cases the first bottom is as distinctly cut into the second bottom deposits, as the water channel is into the first bottom; there being a sudden ascent of from three to as much as ten or more feet, while by a more gradual slope, thereafter, the difference of level often amounts to twenty feet or more. In the second place, not only is there almost always a decided difference between the materials, and consequently the soils and natural vegetation, of the first and second bottoms of one and the same stream (for example 809), but the nature of the latter soil shows a certain correspondence all over the State, so as to be mostly recognizable at a glance by an

CHAPTER VI.

THE TERTIARY.

It is hardly necessary, after having described the quaternary phenomena to state that such of the more ancient marine strata as were not denuded by these inundations are so obscured by their debris, that the determination and delineation of the tertiary and cretaceous stratigraphy is a matter of difficulty, especially in the light of our present imperfect knowledge of these formations throughout the cotton belt. This is especially true of the tertiary, of which only the basal, or lignitic strata are found in the region under consideration, which are here

experienced eye. It is only in the lower portion of the course of the larger streams that this distinction is lost in a great degree.

"The soils and subsoils referred to are mostly pale gray or buff-colored, fine siliceous silts, with but little coarse sand, accompanied by irregularly shaped concretions of bog ore; very unretentative, and poor in phosphoric acid and in lime. Their character varies measurably in accordance with the materials of the bordering uplands, whereas the first bottom soils are chiefly dependent for their character upon the materials in which the bed of the present stream is cut. Beneath the subsoil, we find the materials stratified precisely in the manner described by Prof. Swallow with reference to the 'bottom prairies' of Missouri, to which I have no doubt they are equivalent, as well as to the 'river terraces' described years ago in this journal (by Dr. Newberry, I believe) from observations on the valleys of Ohio. There is but one serious point of difference as regards the former, viz.: that the Bottom prairie contains the fossils of the Bluff formation, whereas the hummock deposits of Mississippi, as far as known, present but a very few and indistinct stems and leaves, occasionally, in the more clayey bands. But it must be considered, that neither is the Bluff formation itself represented on the streams in question. It therefore remains to be determined whether those fossils are an essential characteristic of the Bottom prairie, outside of the region of the Bluff formation, and on the smaller streams. I have not thus far succeeded in discovering any fossils in the somewhat equivocal deposits which seem to represent the 'second bottom' epoch near the mouths of the Big Black, Bayou Pierre, Homochitto and other streams, on the territory of Bluff formation. And as to the existence of any representation of that epoch in the great Mississippi Bottom itself, I have not had any opportunity of observing." E. W. Hilgard in *Am. Jour. Sci.*, May, 1866.

discussed under the local names of the Camden series and Cleveland county red lands.

THE CAMDEN SERIES.

The Camden series underlies the quaternary deposits mentioned at the close of the last chapter. It is an extensive, shallow water, marine formation of stratified, micaceous, non-indurated, alternating laminæ of sands and clay shales, sandy shales occasionally accompanied by bituminous shales, lignitic shales, thin sandstones (quartzites), etc. It underlies the greater part of the country east of the Iron Mountain railway, and is a continuation of similar stratigraphic conditions from other counties of Louisiana, Arkansas and Texas, from the southward.

The coastward limit of this series beyond the St. Louis, Arkansas and Texas railway, has not been studied by the writer, but its beds are known to extend for many miles to the east of Camden, Ouachita county, and to have direct counterparts east of the Mississippi. They have been traced from Camden northward to Pine Bluff, and thence to near Woodson, in the extreme east of Saline county. At Hope, in Hempstead county, artesian borings penetrate the beds of the Camden series for 300 feet, and there is little doubt but that they occupy a large area southeast of that place. They also form the dividing ridge between the Terre Noir and the Little Missouri in Clark county, extending nearly to Rome, while the towns of Smithton and Gurdon are both built upon them.

Owing to the overlying post-tertiary debris, exposures of this formation favorable for study are exceedingly scarce, and it is doubtful whether they could have been seen had the writer not descended the Ouachita river from Arkadelphia to Camden at a time when the water was at the lowest stage known for years,* and even under these advantageous circumstances not over half a dozen favorable exposures were seen

*The United States water gauges at Camden, at the time of this trip, read: "Old guage, 1 foot; new guage, 3 feet; highest water mark, 40 feet."

in the hundred miles of river meanderings between the mouth of L'Eau Fraiss and Camden.

The Camden formation takes its name from the town of Camden, Ouachita county, where its strata are best developed and most conveniently seen in the high bluffs of the Ouachita river. They are the foundation of a large agricultural area, and whatever is to be learned of the possibilities of the region, must be had from the study of these strata. Here the following section was obtained:

Section No. 1, Bluff of the Ouachita River near Camden:

1. Surface soil (residuum of substructure) ferruginous, sandy 5 feet.
2. Laminated sand with greensand specks, originally white, but ferruginating and cementing into red iron sandstone, with a tendency to shaly disintegration on exposure..... 32 feet.
3. Little Missouri lignites, or ligneous shales, with white sand between layers, of the same character as those seen at the mouth of the Little Missouri 20 feet.
4. Buff-colored, micaceous sand and clay shales changing on exposure to pink and light yellow. (The same as those seen in the deep gulches at Camden)..... 10 feet.
5. Bituminous shales, with bituminous masses, and asphalt-like concretions, resembling the so-called "nigger-heads" of the Mississippi tertiary. This stratum is full of concretions of iron pyrites, which oxidize on exposure, coloring the neighboring strata red 15 feet.
6. Light drab, fine, micaceous sands or sandy clays, finely laminated. (The exposures were moist when seen) 25 feet.
7. Concealed 25 feet.
8. Repetition of No. 6 to the water line..... 10 feet.

This Camden section is typical, and presents the most continuous and comprehensive exposure of the formation seen by

the writer. As shown elsewhere, there are many outcrops presenting similar appearances. Judging from the dip it is not probable that these similar strata are identical, but, on the contrary, that they represent alternating conditions in the deposition of a series of beds. Other exposures of the beds of this series have been observed at points along the Ouachita river, as follows, beginning at the top :

Ten Miles Below the Mouth of the Little Missouri.—Bituminous sands and lignites, as seen in No. 5 of the Camden section. Here the dip of the strata can be distinctly seen, which is apparently the same direction as that of the cretaceous at Arkadelphia, showing that there is no considerable non-conformity of direction between the dip of the cretaceous and that of the tertiary.

At the Mouth of the Little Missouri.—Here the south or right bank is a bluff of the lignitic shales and sands a mile or more in length. At no point, however, was a connected section obtainable.

The following is a portion of the bluff as seen about 200 yards below the junction of the Little Missouri and the Ouachita rivers :

Section No. 2, at the Mouth of the Little Missouri River :

- | | |
|--|----------|
| 1. River deposit of yellow alluvium..... | 20 feet. |
| 2. Quaternary iron stone and iron conglomerate, evidently the result of the ferrugination of the underlying gravel and sand..... | 6 feet. |
| 3. Alternating lignitic and sandy laminæ, of the same structure as No. 3 of the Camden section..... | — feet. |
| 4. Chocolate colored micaceous sands of very fine texture | 1 foot. |
| 5. Alternating lignitic and arenaceous laminæ, as in No. 3, to water..... | 8 feet. |

The dip here is distinctly southeastward, which would carry the beds of this section, which are of later age (except the uppermost two members), far beneath the Camden exposures.

At the Mouth of the Big Deciper.—There is a high bluff at the mouth of the Big Deciper, which is fully a 100 feet above low water, and always above high water. The direction of the face of the bluff is southwest and northeast in line with the strike, so that no dip is discernible. The beds consist of fine, micaceous sands, laminated in the upper two-thirds, and alternations of arenaceous and black clay layers at its base, which are more fully described in the L'Eau Frais section. This bluff, at the mouth of the Big Deciper, is the terminus of Copeland's ridge, which for many miles forms the divide between the Terre Noir and the Big Deciper.

Manchester Landing.—Manchester Landing is on section 20, 8 south, 18 west. There is a small bluff on the left side of the river where the following section is exposed :

Section No. 3, Manchester Landing, Ouachita River:

1. Blue and drab, finely laminated, micaceous sands..... 3 feet.
2. Very dark blue, or when wet dense black clay shales. When dry these shales are light blue, and covered with a white efflorescence, like those at Nashville. They are the same as those at the mouth of L'Eau Frais 5 feet.

Mouth of L'Eau Frais.—In descending the river from Arkadelphia, the first exposure seen and, perhaps, the lowest or oldest of the Camden beds were found at the mouth of the L'Eau Frais. They were first observed as an outcrop of dark material near the water's edge, which proved to be the weathering of a clay shale formation. The structure in every detail, except that of consolidation, is the counterpart of that seen in the more ancient shales of the earlier geologic formations, which are abundant in the region north of the mesozoic area; when dry this clay shale weathers into fine scales of a slate blue color.

This is the same stratum as that seen two miles further down the river at Manchester Landing. It has an important bearing upon the agricultural economy of Clark county. It is similar and perhaps identical with the blue clays, seen at lowest

water, in the bluff of Mine creek at Nashville, in Howard county.

At the Mouth of DeRoche.—At the mouth of DeRoche creek is a small patch of alternating sands and lignites, which probably belong at the base of the Camden series. They consist of about 100 feet of alternating sands and lignites, resting directly upon the upturned edges of the paleozoic rocks. This is an isolated patch which has been cut off from the main body of the formation by the erosion of the Ouachita. No cretaceous strata intervene between the paleozoic and cenozoic, at or north of this point.

At Rockport.—Two miles west of Malvern, at the site of the former town of Rockport, there is another exposure of the Camden formation, but it is here accompanied by hard bands of crystalline limestone, containing marine tertiary fossils. This formation rests directly against the disturbed outcrops of the paleozoic novaculite.*

THE ARKADELPHIA SHALES.

In the ravines of the town of Arkadelphia where the overlying plateau gravel has been cut through, can be seen beautifully stratified exposures of blue clays and yellow sands, consisting of alternating bands of these materials, varying from one-eighth of an inch to one foot in thickness. They are best seen in the ravines beside the main streets that lead north from the railway to the business part of the city, in the lateral ravines about 100 yards southwest of the Ouachita Baptist school, and in the ravine two or three blocks north of the court house. There are also good exposures at the Hart place, one mile southwest of the town, at many places on Mill creek, and especially at the crossing of the Big Deciper on the Arkadelphia-Okolona road.

These Arkadelphia clays present very different aspects when freshly exposed and moist, as compared with the same

*Plate A of Owen's "Second Geological Survey of Arkansas" pictures this locality, but Dr. Owen failed to detect the tertiary, which underlies the level region to the east. The writer found fossils in the debris of a well being dug at the time of his visit.

material when dry and after long exposure. In the former case they are a deep blue, and do not readily exhibit their stratified character. Upon long exposure they take on a dirty yellow or brick red color from the oxidation of the iron. Their structural characters, however, are not peculiar to this horizon, for they are repeated, with slight modification, far above in the Camden series. In fact this alteration of sands and thin strata of blue and white clays is the chief structural characteristic of the whole of the Arkansas, Texas, and Louisiana tertiaries.

The following section seen in the ravine and creek a hundred yards southwest of the Baptist school in Arkadelphia, shows the stratigraphic relation of these shales :

Section No. 4, at Arkadelphia.

Quaternary.

1. Stratified yellow clays and gravel, covering the highest points in east Arkadelphia, an isolated remnant of the plateau gravel..... 30 feet.

Tertiary.

2. Arkadelphia shales, consisting of alternate bands of blue clay, and white or orange colored sands. The top portion of this member is eroded and in contact with No. 1..... 5 feet.

Cretaceous.

3. Massive stratum of wet, very argillaceous blue sand, with fossils and yellow ferruginous incrustations 5 feet.
4. Mostly yellow and white sands, with thin layers of blue clay 4 feet.
5. Coarse un laminated cretaceous sands, of a dirty brown sugar color, full of minute particles of green sand, containing many "borings" or cylindrical casts of the High Bluff formation, of which this is believed to be the top..... - feet.

There is a clearly defined line of erosion separating divisions 1, 2 and 3 of this section, although at first sight their

stratigraphic and lithologic differences appear to be small. In fact, were it not for the more extensive observations in the Nashville district and the unquestionable paleontologic evidence, these stratigraphic features could be readily misinterpreted as belonging to the same formation. The difference in superficial color and structure might also be the result of atmospheric conditions. There is no doubt that No. 3, which, upon first exposure appears entirely massive, develops, on drying, a laminated structure. The permeation of ferruginous moisture from the porous plateau gravel deposit which caps the section has much to do with its alteration.

The relation of these strata to the underlying cretaceous is interesting. At Arkadelphia, as shown in section No. 4, the contact, though visible, is that of two massive beds of sand of entirely different ages, but which, macroscopically, give no evidence of conformity or non conformity, and it is only after careful microscopic and paleontologic investigation, or after long exposure at the surface that they can be differentiated.*

At the Big Deciper bluff, however, and other places where the underlying cretaceous beds are of a different material, the nonconformity of deposition between these arenaceous tertiary shales, which are relatively constant in appearance, and the cretaceous Big Deciper beds, is unmistakable. This nonconformity of deposition has also taken place in the Arkadelphia section, but owing to the great similarity of the invading and the eroded formations, it is not there so apparent to the casual observer. The structureless cretaceous sands upon which it

*A visit to Arkadelphia since the foregoing was written, resulted in the discovery of a well defined nonconformity contact between the Arkadelphia shales and the underlying High Bluff (cretaceous) sands. This contact is exposed in the bluffs near the head of the deep ravine that enters the Ouachita immediately north of the cotton factory. Here the surface of the massive blue cretaceous sands (No. 3 of section 4) is deeply eroded and stained with iron, and covered by several feet of false bedded sands and debris, including rounded nodules of the hard tenaceous clay, and the hardened fossils of the underlying cretaceous, especially of *Inoceramus*. Among these fossils was the water-worn smaller end of the cylindrical *Belemnitella mucronata*, the only specimen as yet found in Arkansas, except one found by Dr. Branner in similar debris on the Big Deciper.

rests at High Bluff, however, would not show nonconformity even if these sands had been eroded prior to the deposition of the later shales. At Rockport, beds which present some indications of being identical with these, rest directly upon the disturbed paleozoic rocks. A similar nonconformity between the basal tertiary and uppermost cretaceous is also well shown four miles east of Elmo in Texas.

The impressions of marine fossil shells (*Nucula*, *Crassatella*, *Lingula* and *Ostrea*), in these Arkadelphia clay shales show that they are of marine origin. The impressions of these fossils, however, are all too poorly preserved for stratigraphic identification, and they rapidly lose their characters after exposure.

The Arkadelphia and L'Eau Frais shales virtually have no superficial areal exposures, and are only seen in vertical sections. They are exposed on the margin in most of the streams of Clark county for a few miles south of Arkadelphia. Many outcrops are visible in southern Hempstead, in the vicinity of the county poor farm, and at other places. At Nashville these stratified clays are well shown along the north and south banks of Mine creek in the "old town," where fossil impressions similar to those at Arkadelphia are found. At this place they are covered by the Bingen sands and the plateau gravel, and the stratified gravel of the latter can be seen unconformably resting directly on top of the eroded blue Arkadelphia clays.

THE BINGEN SANDS.

Immediately coastward of and beneath the Howard county gravel plateau, and constituting most of the sandy uplands of eastern Howard, western Hempstead, southern Sevier, Little River, Nevada and Clark counties, is an extensive arenaceous formation which belongs to the Camden series, and which can only be classified as isolated outcrops of the concealed westward continuation of the upper and lower beds of the typical Camden series. The most striking superficial characteristic of this sandy formation, whereby it can be distinguished from the cretaceous sands, is the presence of pine timber, a

characteristic based upon the following geologic reasons, to-wit: that the cretaceous sands are calcareous and glauconitic, and hence favorable to the growth of hardwoods, while the tertiary sands are not so rich in that material, and hence soils derived from them are occupied by the pines. Closer examination, however, shows this formation to consist of a fine white quartz sand, with occasional thin beds of lignite, as at Mineral Springs, Howard county, and near Bingen in Hempstead county. There are also many nodular concretions of iron ore in it, and often extensive layers of ferruginous sandstone, such as are seen two miles out of Nashville, upon the Murfreesboro road, and from one-half to five miles west of Nashville, upon the Locksburg roads, where this formation can best be seen. This ferruginous sandstone is very abundant, and is popularly supposed to be of commercial value as an iron ore. The general character of these sands can best be seen in the vicinity of Nashville, Howard county, the sandy hills north of that town forming the divide between the Ozan and the Mine creek drainage. This divide is 150 feet above either stream, and there is occasional evidence of the rusty plateau gravel formation upon it, but there is not enough of this gravel for stratigraphic determination.

When dry the surface formation is a loose, dirty white sand; and when wet, it is either pure white or light brown, as is the case with beach sand. The iron it contains does not tend to dissemination, but rather to segregation, as is shown by the ironstone concretions.

At a spring one mile north of Nashville small minute specks of ferruginous matter resembling greensand occur. The quantity of clay in this formation is so small as to be almost imperceptible. When wet, however, there is found to be enough to hold the sand together when pressed in the hand. The lignite is very light and unconsolidated, of rare occurrence, and commercially worthless. Two outcrops are elsewhere recorded.

The formation has considerable extent, but the areas are often so irregular and interrupted that it can only be under-

stood by reference to the map. It constitutes the high sandy pine lands of Howard, Hempstead, southern Sevier and central Clark county, and its remnants are found in thin patches upon the divides between the white till and the plateau gravel.

Flowing springs are especially abundant in the sands of the Camden series, and are often impregnated with iron and alum. The springs at Nashville, Dove Park and Mineral Springs are of this character.

The topography of this formation, towards its western margin, consists of highly arched divides from 100 to 150 feet above the drainage beds, making the country a very hilly one, a feature in strong contrast with the level surface of the plateau gravel to the west, and with the more undulating region to the east. Towards the east this formation becomes indistinguishably confused with the Prairie d'Ane formation, which overlies it, the hummocks and mounds being frequent, as may be seen between the towns of Ozan and Nashville. The cretaceous ridges are often capped by a few feet of this formation.

The stratigraphic position and differentiation of the Bingen sands, which so closely resemble the arenaceous formations of the Trinity beds and those of the upper cretaceous, lower cretaceous and Camden series, have been, and still are, a source of perplexity and doubt to the writer. That this formation has much resemblance to that of the Camden series and occupies the same relative position above the Arkadelphia shales, is undoubted, while much of the country along the Gurdon and Camden road is identical in appearance. At Nashville, as has been shown, these sands are, hypsometrically above the well defined gravel, unless the latter is unconformably deposited lower in eroded channels, which seems very probable. At Mineral Springs, Centre Point, and other places, however, there is undoubted evidence that this formation, or the sands of another formation indistinguishable from it, is below the plateau gravel.

THE CLEVELAND COUNTY RED LANDS.

The "red lands" of Cleveland county constitute a fossiliferous horizon at or near the top of the Camden series. This

formation consists of the characteristic sediments of that series, but is accompanied by extensive deposits of marine shells and greensand which bring into these strata an ingredient of lime, an ingredient which is conspicuously lacking in the underlying beds. This lime renders the otherwise almost sterile micaceous sands and clays a fertile calcareous marl. The original marl and calcium carbonate is frequently dissolved out and replaced by iron, from which the local name of "red lands" is derived. The fauna consists of *Cardita planicosta*, Lamarck *Calyptrophorus (Rostellaria) velatus*, Conrad, and many other characteristic forms, some of which are illustrated on Plate IX of Owen's Second Geological Survey of Arkansas. These fossils are all characteristic of the Claiborne formation of Alabama and Mississippi, but the present condition of knowledge concerning both the Arkansas and trans-Mississippi beds does not justify extensive taxonomic discussion here. These beds are identical, however, with the iron bearing red lands of Rusk, Cherokee and other counties in northeast Texas.

GENERAL CONCLUSIONS CONCERNING THE CAMDEN SERIES.

From an examination of the outcrops along the river banks from their residual soils, and from a knowledge of the substructure as indicated by artesian well borings, the writer believes that much of the yellow pine region of southern and southwestern Arkansas is based upon this well defined Camden series of stratified marine sediments, although the quaternary covered surface does not always suggest this fact. The sediments of this series are probably lower tertiary, although there are but few fossils to indicate their age.

Besides the great beds of lignite, fossil dicotyledonous leaves are often reported throughout the series by well diggers, but they are seldom found in a condition to maintain their form upon exposure to the atmosphere. The shallow water origin of the formation is attested by the character of the sediments themselves, and especially by the alternating bands of clays and fine sands, which show that they were deposited in shallow marine waters, within the limits of estuarian

sedimentary precipitates and influenced by tidal wave action. Such deposits are probably now forming off the coast of the Gulf of Mexico where the waters are shallow, and where the mingling of the gulf currents and the sediment laden fresh waters from the Mississippi river would aid the sorting of clays and sands, and the deposition and burial of driftwood such as forms the lignite beds of the Camden series.

The sands of the Camden series correspond to the descriptions of the "Mansfield series" of the Saline basin of Louisiana, as originally described by Hilgard,* and later by Johnson,† but those descriptions are so brief, and all the cenozoic formations are so similar that any attempt at correlation, without personal investigation of both localities, would be unsafe.

The total thickness of the Camden series cannot be accurately stated, but at the slight dip noted, it cannot be less than 700 feet between Curtis and low water at Camden. At the latter place, nearly 300 feet more can be seen in the bluffs and hills which rise far above the river. Artesian wells have been reported at various depths which confirm the estimates. Like the other formations much of it has been removed by the great quaternary inundation.

The stratigraphic character of the Camden series, as a whole, such as the fineness of lamination, the alternations of micaceous, argillaceous, lignitic, and arenaceous layers, its uniformity in extent, together with the few marine fossils known to occur sparsely at its base and top, its unconformable position upon the cretaceous, and its shallow marine origin, all show that it is the earlier tertiary of the Gulf States, as described by Dr. E. W. Hilgard in northern Mississippi, Alabama, and Louisiana.

In Mississippi, Tennessee and Alabama, beds of apparently similar lithologic, stratigraphic conditions and relations as these occupy the same relative geologic and geographic posi-

*Supplementary and Final Report of a Geological Reconnaissance of the State of Louisiana, 1869, New Orleans, 1873, pp. 20 to 23.

†Report of the Iron Regions of Northern Louisiana and Eastern Texas, Washington, 1888.

tions, though of course the identity of formations on the two sides of the Mississippi cannot be stated until after a study has been made of the formation as a whole, regardless of State lines. Neither can any minute subdivisions of these beds be attempted at present. There can be but little doubt, however, that this great formation, or formations of similar structure, extends from Arkansas and Louisiana into Texas almost continuously as far as the Colorado, and from thence towards the Rio Grande near Laredo, where it approaches and is closely related to the great Laramie beds of the interior continental and Rocky Mountain regions. All of Texas east of the Black Prairie region and north of the Brazos river, including the sandy pine lands, is identical with this formation, and it is in that region that it attains its typical development.

Owing to the absence of a satisfactory stratigraphic section of any typical portion of the southern tertiary, it is of course impossible to correlate this series with any definite horizon, except to say that it is typical of the basal tertiary. The principal and most marked structural character of the formation—the alternation of horizontal strata of fine unconsolidated, laminated sands with usually thin bands of almost pure white or blue clays—together with occasional beds of lignite, prevails in nearly all the subdivisions of the tertiary of the Southern States, as described by Hilgard in Mississippi and Louisiana, and as seen by the writer in Northeast Texas. Judging from descriptions of the Mansfield and Sabine Town strata near the Louisiana-Texas boundary, these also partially resemble the Camden strata of Arkansas, as well as do those of all the region along the Texas Pacific railway from Texarkana to the Neoches. The occurrence of well defined Clarbornian fauna in what is supposed to be the upper limit of the series, to wit: the Cleveland county red beds, especially when strengthened by collateral lithologic data, suggests their affinity with the beds described by Hilgard in Mississippi.

The main or lower beds of the Camden series, however, bear special resemblance to those described by Dr. Hilgard under the name of the "great northern lignite," and doubtfully

placed by him* at the base of the whole tertiary system. Professor Angelo Heilprin has recently proposed† the more euphonious name of "Eo-lignitic" for this group, and has theoretically extended its application so as to include the formation in Arkansas and Texas. The writer's observations of this basal tertiary tend to confirm Professor Heilprin's opinion, that the Mississippi eo-lignitic beds "doubtless extend for a considerable distance into Arkansas, entering largely into the formation of the Mississippi embayment, and meet their continuation on the other river in the State of Mississippi."‡

The relation of the later cretaceous and early tertiary strata of the Gulf States, to those of the interior or Rocky Mountain region has been an interesting subject of geological speculation, inasmuch as it has been generally supposed that near the close of the cretaceous, a great land barrier was elevated approximately along the 100th meridian, cutting off from the main waters of the Atlantic ocean a great interior continental sea which covered much of the present Rocky Mountain region, and which continued through many vacillations in areal extent and salinity, from that time almost to the present, no later marine bed having been deposited in that region. The uppermost cretaceous in the West, without any visible break in sedimentation, as recorded solely upon fossil evidence, gradually changes from marine to brackish and from brackish to fresh water deposits, there being no undoubted marine deposits in that region of later age than the Fox Hills formations of the cretaceous. The age of the Laramie beds, however, has been a subject of much dispute, but it has been generally conceded that they were transitions between the marine cretaceous and the fresh water tertiary of the western United States. The basal eo-lignitic deposits of the Arkansas-Texas region, which have been traced to within a score of miles of the undoubted Laramie beds in northern Mexico, are,

*Agriculture and Geology of Mississippi, p. 109.

†Contributions to the Tertiary Geology and Paleontology of the United States, by Angelo Heilprin, Philadelphia, 1884.

‡Op. cit., pp. 32-33.

so far as can be observed, a continuation of the latter. The conditions of deposition, the one in marine brackish, and the other in lacustrine brackish waters, and the component materials of the respective sediments, are very similar, and although differing greatly in solidification, those of the far west have been consolidated and hardened by the different conditions to which they have been subjected since their deposition. Had these sediments of the Camden series been exposed to similar conditions of later disturbance and metamorphism as those of the Laramie, they would now be identical in lithologic facies.

Both the eo-lignitic and the Laramie are brackish water deposits, laid down where the fresh waters from the land freely mixed with those of the ocean on the one hand, and with the saline waters of an inland sea on the other. Both at first consisted of ferruginous sands, derived from the post-cretaceous land area accompanied by great deposits of vegetal matter, much of which has since become lignitized. Molluscan remains are comparatively scarce in both formations, although those discovered in the Laramie are of a markedly different type from the few so far found in the eo-lignitic, the former being brackish while the latter are marine. This is not so with the vegetal remains, however, for according to Professor Lester F. Ward, the plant remains, which have been but little studied from the eo-lignitic beds, show a marked identity, and, we think, signify synchronism of growth and deposition. Speaking of the plant remains from the Laramie, Professor Ward says: "The number of Laramie species that also occur in the Eocene, as defined in the table, is quite large, amounting in all to thirteen or fourteen. Seven of these are confined to these two formations, which might afford strong *prima facie* evidence of the close affinities of the Laramie and Eocene floras. This evidence, however, is greatly weakened when we perceive that of these seven, four occur in the supposed Eocene beds of Mississippi, and not in any of the Old World deposits. *This is certainly strong proof of the close relationship of these Mississippi beds to those of the Laramie*, as well as of their similarity of age, but it is more interesting as show-

ing that in those early tertiary times one great homogeneous flora stretched all the way across the North American continent, and that similar forests fringed the waters of the Gulf of Mexico during their southward retreat, and those of the Laramie sea as it shrunk to the proportions of inland lakes. The difference of time between the two deposits, though it might have been great, was not sufficient to alter the specific identity of these four forms and doubtless of very many others, while in other cases the Laramie species may represent the ancestors of the Eocene species found, or to be found, in the more eastern deposits. These species are *Sabal grayanus*, *Populus monodon*, *Magnolia hilgardiana*, and *M. lesleyana*, all of Lesquereux. All except *Magnolia hilgardiana* occur only in the typical Laramie deposits of the more southern districts, but this species has now been reported also from the Yellowstone Valley, which, of course, relegates it to the Fort Union group.”*

Although this evidence is but fragmentary, it throws some light upon the relation of the interior, continental and Gulf States’ basal tertiaries, and it is probable that these two formations—the lacustral Laramie of the West, which has hitherto been supposed to be of cretaceous age, and the near shore sediments of Southern States, which are undoubtedly tertiary—are approximately synchronous in deposition.

The following opinion of Dr. C. A. White has also been published, which, although based upon confessedly doubtful data, is corroborative of these views. “Indeed, so far as I could discover, no equivalent of the ‘Northern Lignite,’ the lowermost member of Hilgard’s Mississippi section, exists in the region around Laredo (Texas), unless the coal bearing strata of the upper portion of the Laramie are really its equivalent.† I am disposed to accept this view of the case,

* Sixth Annual Report of U. S. G.S. p. 529. Flora of the Laramie Group, by Lester F. Ward.

†Recent investigations have shown that the upper coal beds of the Rio Grande are the direct continuation of the Southern States lignitic, and that they rest unconformably upon the cretaceous beds. Finally, the decided and persistent noncon-

and to regard the Northern Lignite of the Mississippi section and its equivalent elsewhere, including the uppermost strata of the Laramie, as really of Eocene age."*

formity between the Camden series, or basal tertiary, and the various horizons of the paleozoic and upper cretaceous are indicative of a considerable land epoch succeeding the last mentioned period, which must have extended throughout central Texas, separating the marine waters of the east from the enclosed Laramie basin of the west.

*Am. Jour. Sci., June, 1888.

CHAPTER VII.

THE CRETACEOUS GROUP.

This group of rocks upon which the most productive portions of southwestern Arkansas are based, is one of the most important in the United States, both in extent and value of its economic products, and from a scientific standpoint. It comprises the marl beds of New Jersey, from which agriculturists of that State have realized incalculable benefit; the rich uplands of the interior cotton belt of the trans-Mississippi Southern States, and by far the most fertile lands of Texas and southwest Arkansas. Much of the grazing lands of the great plains is based upon it, and in the Rocky Mountain region, including the lower Rio Grande country, where it has been subjected to metamorphism, it yields the coal supply of the prosperous far west. From its debris, when transported by the many streams which transect its loosely segregated strata, have been derived not only the present rich bottom lands, but the fertile ingredients of the formations between its borders and the present Atlantic coast.

From a purely scientific standpoint the cretaceous strata of Arkansas are interesting, first, in that they embrace the entire vertical thickness of the beds of cretaceous age as known on this continent, including all the diverse marine cretaceous formations from bottom to top, and, secondly, because they form the northeastern termination of the great development of the lower cretaceous system west of the Mississippi river, and the western border of the upper cretaceous of the Atlantic and Gulf States, throwing much light upon this system as a whole.

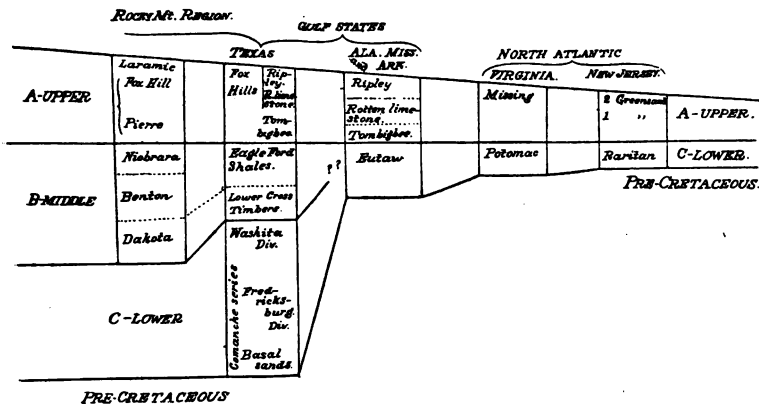
The rocks of the cretaceous system in Arkansas belong to two entirely different stages or formations, the upper and lower, and for the purpose of discussion, they are spoken of in this paper according to their stratigraphic and paleontologic characteristics as two chief divisions:

1st. *The Upper Cretaceous or Exogyra Costata Series.*

2d. *The Lower Cretaceous or Comanche Series.*

In the American Journal of Science, Vol. xxxiv, October, 1887, the writer has given a brief explanation of the cretaceous system of the United States, as it has been understood through the accepted publications. Its repetition here will save much extra explanation in the following pages :

"There are at least five widely separated areas where the system has been independently studied by different authors, but little or no work has been done to trace the direct stratigraphic relations between them. In each of these areas, except the Californian, which will not be touched in this paper, the North Atlantic (including New Jersey, Maryland, District of Columbia, Virginia, and the Carolinas), the Gulf (including Alabama, Georgia, Mississippi, Tennessee, Arkansas, and eastern third of Texas), the Rocky Mountain (including the Trans-Pecos and Lower Rio Grande region of Texas), the principal subdivisions recognized are those of the following table. *



"It is evident from a careful study of the faunas and stratigraphy of these regions, that throughout them all, within the limits which I have marked, exists a great similarity of molluscan fauna, both specifically and generically, although the lithologic and stratigraphic characters vary in each. To the local formations of this collection of strata many different names

*"The solid lines represent complete faunal breaks, and the dotted lines indicate subdivisions whose species range into the including formations."

have been given, and nearly every horizon has been termed a 'group' regardless of any specific definition of that word, which has been used with an indefinite meaning in all the nomenclature of the American cretaceous. Instead of indicating a plurality of related phenomena, it has usually been applied indiscriminately to single characteristics based upon lithologic or specific culminations. For instance, in the Alabama regions the 'Tombigbee sands,' the 'rotten limestone,' and the Ripley beds have each been called 'groups,' when in reality together they constitute but a single group, as interpreted by the present accepted meaning of that word, their lithologic features being the fluctuations of an unbroken sedimentation, and the molluscan fauna continuous or interwoven by connective species from top to bottom. The 'groups' so-called, are really 'horizons,' representing the culmination of species or sedimental variations. The same can probably be said of the New Jersey cretaceous above the Raritan clays, and the Fox Hills and Pierre 'groups' of the Northwest. The entire collection of strata of this upper portion of the American cretaceous together constitutes a group which has been correlated with the upper cretaceous of Europe, but until our stratigraphic studies are completed, can only be called the upper cretaceous.

"In the Rocky Mountain and Texas regions other marine formations exist, but they have not as yet been traced east of Central Texas. These include the Benton, Niobrara and Dakota sandstone groups of Meek and Hayden, which these geologists correlated, for good reasons, with the lower chalk or greensand of Europe. The state of knowledge concerning the American cretaceous does not justify any more specific term to these as a whole than 'the middle cretaceous.'

"In all four of these regions above mentioned the undoubted open sea or marine groups rest upon the problematical formations of more shallow sediments, consisting of clays and sands, unaccompanied by any distinctive molluscan faunas, but a great abundance of vegetable remains, such as Dakota sandstone in the Rocky Mountain region, the Eutaw beds in the

Alabama region, the Potomac beds in the Virginias, and the Raritan clays, in New Jersey, the relation of which to each other has not been published and is still a fertile question for investigation."*

These cretaceous strata present a great diversity of appearances, which is due to the fact that the system, as a whole, is composed of two entirely distinct formations, separated by a complete faunal and stratigraphic break, which shall be discussed in this paper under the general heads of the "upper and lower cretaceous," meaning by the former the stratigraphic equivalents of Meek and Hayden's section of the American cretaceous, from Nos. 1 to 58, inclusive, and by the latter the equivalents of the Comanche series (with modifications), as published by the writer in the American Journal of Science for April, 1887.

*Some important unpublished observations, which the writer does not feel authorized to use, have been made of late in these basal groups by McGee, Fontaine, Smith, Johnson and others.

CHAPTER VIII.

THE UPPER CRETACEOUS, OR EXOGYRA COSTATA SERIES.

[The cretaceous section of Meek and Hayden; Ripley, rotten limestone, and Tombigbee sands (in part) of Hilgard; Kreide am Fusse des Hocheslands (in part) of Roemer; Navarro county, Texas, beds of B. F. Shumard; lower marl beds of New Jersey.]

This series includes in Arkansas and Texas a variety of continuous but often differently appearing beds of the upper cretaceous, varying from sands to clays, clays to chalk, chalk to chalky marls, and from the latter to sand again; and it will be readily recognized by those familiar with the Arkansas, Texas, Alabama and Mississippi regions as the "black land," "green sand," "white marl," "blue dirt," and "yellow clay" formation of Okolona, Ozan, Columbus and Brownstown, and the adjacent sandy upland strata, as at Washington in Hempstead county. This series is by far the most extensive in the cretaceous subdivisions of Arkansas, and is the most eastward in geographic position. It occupies the Marlbrook-Columbus divide between the areas covered by the plateau gravel region and the Prairie d'Ane beds of the quaternary. Its principal occurrence, following a northeast and southwest strike, is in central Clark, southwest Pike, northwestern and central Hempstead, southern Howard, and the southeast corner of Sevier counties. Its most eastern and most northern outcrops are in the bed and along the banks of the Ouachita river, from low water mark at the Iron Mountain railway bridge at Arkadelphia to the mouth of the Caddo, some seven miles up that stream. All these exposures, except one at "Aunt Eliza's Bluff," are upon the south side of the river, and are invariably covered by later tertiary or post-tertiary strata. Similar outcrops form the bluffs of the Little Missouri and Red rivers to the southward, but in no case, yet observed, do they extend to the east of the Iron Mountain railway. Proceeding westward from the Ouachita river these outcrops have wider and wider

exposures, until they are obscured upon the west by the great gravel plateaux. The most extensive area of its outcrops is the high region of the Columbus-Marlbrook divide, between Little river and the Little Missouri river, and its northern continuation in Clark county, as seen at Okolona and Hearne. Everywhere, however, this formation is more or less covered by quaternary deposits, and the ridge just mentioned seems to be an old shore line or base level of the later Prairie d'Ane beds. In fact its eastern slope is covered with its own debris, produced by the action of the quaternary waters. This action is exemplified east of Washington, near Gurdon, at Fulton, Columbus, on section 11, 11 S., 26 W., in Hempstead county, and all along the eastern border of the Black Prairie of Texas.

There are no extensive exposures of the cretaceous beds in Arkansas south of Little river, their continuity over the Red river valley into Texas having been denuded in the valleys and covered in the highlands by post-tertiary deposits in Louisiana and Texas. Isolated areas of the cretaceous occur far to the southeast of the immediate region treated.

In places the post-tertiary debris is so shallow that the presence of the cretaceous subsoil is shown by its effect upon the vegetation, as in the hardwood forests between Ozan and Mine creek at Nashville. The western outcrops of the present remnant of the upper cretaceous series proper are along the paleozoic border in Clark county, which approximately coincides with the Caddo-Antoine military road, and in Pike county with the Antoine-Murfreesboro road in Hempstead, it is along the south bank of the Ozan, and the east bank of Mine creek. In southern Howard it forms an extensive area south of the Brownstown and Ben Lomond plateau, and thence it continues west to Paraclifta, Sevier county, where the last traces of it are seen beneath the quaternary in the medial slopes of Little river. All along this western line it is obscured by the eastern and southern border of the gravel plateau, which is deposited uncomformably upon it, and which obscures its parting with the underlying Comanche series.*

*See map and sections.

How extensive the denudation of the upper cretaceous has been, and how little of its original extent the present area represents, can hardly be determined, but it is certain that the present beds were greatly denuded by the deposition of the tertiary and quaternary strata, and at present are undergoing rapid surface degradation, so that what is visible of them can only be a fraction of their original thickness and extent.

For the purposes of discussion the upper cretaceous as a whole is divisible, as mentioned below. The formations spoken of do not represent faunal or stratigraphic breaks, but are uniform and apparently persistent stratigraphic horizons marked by the culmination of some lithologic and paleontologic feature, but between which there is every gradation.

THE DIVISIONS AND BEDS OF THE UPPER CRETACEOUS.

A. *The Upper Arenaceous Beds.*

1. The Washington-High Bluff greensands.
2. The High Bluff blue sands.
3. The Big Deciper calcareous sands and sand rock.
- 3a. The Clark county littorals.

B. *The Chalky Marl Beds.*

4. The Marlbrook-Columbus, or *Gryphæa vesicularis* chalk marls ("rotten limestone.")
5. The Brownstown, or *Exogyra ponderosa* yellow clay marls.
6. The White Cliffs chalk.
- 6a. The White Cliffs basal, or glauconitic chalk.

C. 7. *The Rocky Comfort (Niobrara) Chalk.*

D. 8. *The Eagle Ford Clay Shales.**

E. 9. *The Lower Cross Timber (Dakota) Sands.**

A.—THE UPPER ARENACEOUS BEDS.

1. *The Washington or High Bluff Greensand Beds.*—Along the river bank and adjacent ravines immediately beneath the Arkadelphia shales at Arkadelphia, and generally concealed by them, as has been shown in the section last given, there is a series of dull brown sands, with occasional bands of sand-

*Horizons D and E do not outcrop in Arkansas.

stone, different in lithologic character from the great series above it. These sands are coarser, less argillaceous, free from stratified clay bands, are more or less rich in greensand, and contain occasional beds of firmer, dark colored, crystallized calcareous strata, from one to two feet in thickness, or round boulder-like sandstones resulting from local hardenings and filled with cylindrical, tube-like casts of fossils, and the impressions of *Baculites*. The casts seem to be siphonal casts of marine mollusca. There are also many true concretions often two feet in diameter, the nuclei of which seem to be a fossil crustacean (*Callianassa*), and mollusks, *Exogyra costata*, and *Inoceramus*, etc., predominating. The sandstones of this formation are seen at lowest water along the west margin of the Ouachita river from one hundred yards north of the Iron Mountain railway bridge up and along that stream continuously as far as the termination of the High Bluff, about one mile and a half northeast of Arkadelphia. At the last mentioned point the first exposure of the formation in this vicinity is seen in a perpendicular bluff of over a hundred feet. The following is a crude section of this bluff:

Section No. 5, High Bluff of the Ouachita in Section 8, 7 S. 19 W. (Dip 5° S. E.)

- | | |
|--|----------|
| 1. Surface soil, highest point of bluff; quaternary drift and lemon yellow soil from 2..... | 3 feet. |
| 2. Gray and brown sands, containing small black particles (glauconite?) and fossil casts..... | 25 feet. |
| 3. Band of coarse, crystalline sandstone, loosely cemented, containing fossils and "cannon ball" nodules | 4 feet. |
| 4. Sands as in 2..... | — — |
| 5. Sandstone, one foot..... | 1 foot. |
| 6. Continuation of these alternations of sands and sandstones for..... | 80 feet. |
| 7. Blue micaceous, fossiliferous sandy marls or "blue dirt" of the next formation..... | 50 feet. |

These beds reappear at intervals further up the Ouachita to a point above the mouth of the Caddo, where they finally

disappear. They are seen at one place east of the river, at "Aunt Eliza's Bluff," on section 3, 7 south, 19 west. They can also be traced up Mill creek for a few hundred yards. In Clark county they occur along the sides of the Terre Noir basin, and notably at Major J. Ross's, near the mouth of Bradshaw creek, and again fine outcrops occur at the Nacotoch bluff of the Little Missouri, section 3, 9 south, 20 west, where there is a grand exposure, perhaps the best of all the region. At this point the sands and firmer bands alternate in a bluff 100 feet in height and two miles long. This bluff presents slightly different facies from the one above Arkadelphia, but only in a fuller development, both stratigraphically and faunally.

It is also probable that much of the sandy beds forming the forest covered surface between Arkadelphia and Rome along the public road belongs to this formation, but the writer has thus far been unable to differentiate it, by the surface appearance, from the sandy strata of the overlying tertiary and post-tertiary formations.

These outcrops in Clark county occur mostly along a southwest line, which, if followed across the Little Missouri river to Washington in Hempstead county, will cross several other outcrops of this horizon, exposed where the drainage system has worn through the post-tertiary sands of the higher divides. Three miles northeast of Washington the highest slopes on both sides of Pate's creek valley are composed of these beds, which outcrop next in the vicinity of Washington. The town of Washington is situated, for the most part, upon heavy sands, through which numerous ravines, the secondary drainage of Mine creek, have cut down to the cretaceous sands. So similar are the macroscopic appearance of the cretaceous, tertiary and post-tertiary deposits, the latter, no doubt having been in part derived from the former, that they can scarcely be differentiated. A careful study, however, reveals an erosion plane between them, usually accompanied by a thin stratum of white quartz gravel, averaging the size of a pigeon's egg, as seen on the main street near the Judge Eakin place,

and on the north side of the Town creek flood plain near Gen. Garland's old homestead. At the latter place the sands are especially rich in glauconite—so much so as to be almost entirely composed of that substance in places, and contain frequent bands of fossils, being very rich in the costate variety, of the *Exogyra costata*, Say, *Gryphæa vesicularis*, Lamck, especially the variety known as *Gryphæa vomer*, Morton, and the narrow incurved varieties; *Ostrea larva*, and numerous casts. The abundance of these oyster shells adds much lime to the beds, and often the glauconitic grains are cemented by a calcareous matrix into a firm rock, which crumbles, however, upon exposure. The oxidizing of the greensand in these beds gives a lemon tinge to their residual soils, a feature which is also noticeable in Clark county between Rome and Okolona.

At numerous places in the deeper creeks on all sides of Washington the same nodular masses and stratified bands of limestone, as at High Bluff, occur. The foundation of Hempstead county court house is built of this material.

The Washington greensand and High Bluff beds are rich in fossils, which, excepting *Ostreidæ*, occur mostly in the form of casts. These fossils exhibit a tendency to occur in colonies, and the quantity of individuals of a species varies in different localities, but usually all of the forms are found in any single locality.*

The dark colors of the material of these beds is in strong contrast with the white rock or rotten limestone and blue dirt of the lower formations, and with the finely stratified Arkadelphia shales sometimes found above it.

2. *The Blue Sands of High Bluff and of Pate's Creek.*—At the upper end of the High Bluff of the Ouachita, the above described Washington greensands can be seen resting con-

*The principal forms are *Scaphites*, sp. ind., *Turritiles*, sp. ind., *Baculites grandis*, *Baculites ovatus* Say; *Caelianassa* sp. ind., *Ostrea* sp. ind., *Gryphæa vesicularis*, *Ostrea larva*, sp. ind., *Exogyra costata*, *Pecten*, *Spondylus*, *Inoceramus*, *Legumen*, *Arca*, *Axinaa*, *Nucula*, *Cardium*, *Protocardium*, *Pachycardium spillmani*, *Turritella*, sp. ind., *Natica*, *Fusus*, etc., and many other casts, besides a persistent bryozoan, which often occurs in extensive masses.

formably upon a more massive bed of dark blue, fine, micaceous, sandy marls, which dip beneath the overlying beds. At the Pate's creek crossing of the military road, three miles northeast of Washington, the same relation can be seen, as in the following section:

Section No. 6. Valley at head of Pate's Creek, at the crossing of Washington-Wallaceburg road.

Altitude above
creek in feet.

1. Post-tertiary sand and gravel, one mile north of creek . . 190
2. Red residual soil from No. 3 180
3. Washington greensand beds with large *Exogyras costatas*, and large *Gryphæa vesicularis* (var. *pyncnodonta*). 100
4. Firm stratum of dark limestone, one foot of which is full of large *Turritellas* 60
5. Blue colored sandy marls with calcareous efflorescence, as at High Bluff of the Ouachita, with bands of limestone at intervals of four or five feet 30
6. Blue marl as in 5, but without hard layers. Very fossiliferous, including colonies of the deeply six lobed serpula ("cock-spurs") and *Cassidulus*. 20
7. Bed of creek 0

The downward continuation of these beds is here obscured, but they are seen a few miles west in the cuttings of the Arkansas, Texas and Louisiana road.

The High Bluff beds are met with in wells throughout the valley of the Caddo, and at many places along the military road, as far south as the old Trigg homestead. In the fresh strata penetrated by these surface wells are found many shells, which crumble almost immediately upon exposure, and are perfectly similar in character to those found in certain beds of Mississippi.*

*At Pate's creek the following fossils were noted, which, it will be seen upon comparison, belong to the same fauna as that of the overlying Washington greensands. *Lamna*, *Baculites grandis*, *Bovatus*, *Ancyloceras*, sp. ind., *Cassidulus* (very abundant), *Exogyra costata*, *Ostrea larva*, *Pachycardium spillmani*, *Cardium tippiana*, *Crassatella ripleyana*, *Astarte conradi*, *Dosinia*, *Lucina*, sp. ind., *Anomia argenta*, *Turritella*, sp. ind., *Fusus*, sp. ind., *Dentalium*, sp. ind.

Upon comparing these blue sand beds with the overlying greensands, it will be found that, while having the same fossils, they differ as follows:

1st. By the great amount of glauconite in the sand beds, and—

2d. By the increasing amount of lime, either efflorescent or segregated in hard crystalline bands in the blue sands.

3. *The Big Deciper Calcareous Sands.*—It will be seen that these sandy phases of the upper cretaceous become more and more calcareous as we go down geologically. Where the Arkadelphia-Camden road crosses the Big Deciper in Clark county, on the south bank of that stream there is a bluff of white, unstratified rock, consisting of grains of sand like those of the above mentioned blue sands, and containing occasional grains of greensands, full of casts of shells, and especially the large *Exogyra costata*, all of which is cemented by a calcareous matrix. This white formation has the lithologic appearance and weathering of the soft white, chalky marl, sometimes found near it and known throughout the south as "rotten limestone."* Upon being dropped into the water the matrix of this rock dissolves, leaving a remnant of brown sand, similar to that of the High Bluff formation. When moistened it turns blue like the next succeeding formation. Upon close examination it is found to be full of casts of fossils, from the dissolution of whose shells no doubt much of the calcareous matrix has come. At Major Jesse Ross's place, near the mouth of Bradshaw creek in Clark county, and west of the high bluff near Arkadelphia, the characteristic high bluff sands and sandstone are seen resting directly upon or rather changing into these beds. Similar phenomena occur along the railway north of Washington. At the Big Deciper, however, the Arkadelphia shales rest directly and unconformably upon the Big Deciper formation, a slight deposit of blackened quartz pebbles being found along the somewhat irregular line of contact, showing

*The expression "rotten limestone" is not used in this paper to indicate a specific horizon, as in Mississippi; but only as a descriptive lithologic term.

that the overlying sands were denuded before the deposition of the tertiary beds. The top of the Big Deciper formation is only twenty feet above the water level at Big Deciper creek, and it dips beneath the stream a mile southeast of this place. It rises correspondingly to the westward, so that at the Boseman place, some two miles above and west of where it crosses the road, its base is fully 100 feet above the creek, resting upon the beds next to be described. These Big Deciper beds are also exposed in Clark county, at the crossing of the Little Deciper creek on the Okolona and Mount Ida road; at many places in Mill creek, south of the High Bluff; at Dobyville, Okolona and at other places. Its area increases southwestward, so that it attains great development in the neighborhood of Okolona and Dobyville, where, owing to the fact that it is excavated for reservoirs and readily holds water, it is termed "cistern" rock. The fossils of this horizon are numerous, but they are mostly preserved as casts. There are no broad paleontologic lines between this bed and the overlying and the underlying beds, and although it is a constant and definite horizon, there are several repetitions of its lithologic characters, a transition from chawks to sands, in the descending series. At the base of the White cliffs of Little river, near the corner of Hempstead, Howard and Little River counties, this lithologic peculiarity is clearly repeated beneath the chawks described farther on.*

In Hempstead county a transition from the blue sands of the Pate's creek section can be seen along the railway northwest of Washington, the sands becoming gradually more argillaceous and more calcareous, until the first deep cut is reached, where the typical Big Deciper phase is beautifully displayed.†

*The following fossils are quite common and characteristic of the Big Deciper calcareous sands: *Baculites ovatus*, *Trigonia*, *Arca*, *Anomia*, *Exogyra costata*, *Cassidulus*, *Pachycardium spillmani* and others, which (except the *Ostreidae*), are mostly in the form of hard casts. The typical ribbed variety of the *Exogyra costata* prevails in these beds.

†Here were found *Baculites*, *Ancyloceras*, *Nautilus de kayi*, *Gryphaea vesicularis*, *Exogyra costata*, *Exogyra ponderosa*, *O'falcatia*, *Camptonectes*, sp. ind., *Pecten*, *Anomia argenta*, *Inoceramus*, *Turritella*, *Fusus*, etc. (mostly casts), and

From this portion of the section downward there is a marked difference in detail between the upper cretaceous as seen in the Clark county and in the Hempstead county cross-sections. This is owing to the fact that in the former region the section is soon terminated by the littoral contacts with the paleozoic region, while in the latter region the older and deeper water sediments continue, so that there are still many thousand feet of older calcareous cretaceous strata between the *Gryphaea vesicularis* horizon and the paleozoic contact, while in Clark county these upper beds of the upper cretaceous or *Exogyra costata* series are in direct contact with the paleozoic. The great erosion of the Little Missouri valley, and the quaternary deposits of the Howard county gravel plateau, have made it impossible to trace the continuity of these sediments further.

The deposits spoken of here as the "Clark county littorals," namely, "the second blue dirt," "the Koster joint clays," and "the Big DeGray beds," are purely local ones, and have therefore been given no place in the synoptical table of the widespread formations of southwestern Arkansas. They are probably the littoral or near shore beds deposited at the time when the three preceding and the three succeeding beds were being deposited in deeper waters.

3a. *The Clark County Littorals—The Second "Blue Dirt."*—Continuing up the divide of the Deciper, in Clark county, across the strike of the formations, the paleozoic contact is soon reached, and the downward development of the cretaceous seen elsewhere is missing. The higher beds are but continuations and alternations of condition of deposition of the two lower ones, which owing to their position relative to the old shore line, are here more or less arenaceous. The yellow marls last described as appearing in the creek bottoms at Boseman's and dipping eastward, two miles west of that place, are found capping the highest divides, while cropping out beneath them is found a bluish, marly, calcareous sand, in some respects like

imbedded in a small piece of lignite, evidently a fragment of an ancient log that had reached these deeper but mild waters, was a beautifully preserved colony of *Teredos*.

the High Bluff beds, rich near the top in fossil remains of the small crenulated oyster, *Ostrea larva*, and of the hemispherical oyster, *Gryphæa vesicularis* var. *convexa*, locally called "skulls." These marls are first found at the upper end of the Boseman place, but are better displayed in the ravines, or branches of the Deciper and Bradshaw creeks, in the vicinity of Hearne, and especially in the well dug at Allen's old gin-house on the southeast quarter of southeast quarter of section 17, 7 south, 20 west. The following section represents the sequence and estimated thickness of the formations in the vicinity of the old cotton-gin mentioned above :

Section No. 7.

1. Arkadelphia-Mount Ida Road. Deserted farm. *Exogyra ponderosa* marls..... 25 feet.
2. Allen's gin-house. Gray sands, rich in fossils (*Ostrea larva*, *Pecten quinquecostata*, young of *Gryphæa vesicularis*. "*Ostrea vomer*," Say, *Dentalium* sp. ind., etc.) This sand is quite free from coloring matter..... 20 feet.
3. Hard stratum of rock with casts of fossils, as in Big Deciper formation 1 foot.
4. Gray and blue marls, mostly sand, containing many specimens of the *Gryphæa vesicularis*, var. *convexa*, and *Exogyra costata*..... 100 feet.

This "blue dirt," as these sands are locally called throughout the region, is alleged by those who have dug wells through it, to be 250 feet deep. This statement is not geologically accurate, for the writer's observations show that this thickness includes not one continuous lithologic feature, but several alternations or horizons of the so-called "blue dirt," and "joint clays" of the vicinity. There is also a difference in the richness of these "blue dirt" which has a bearing upon their agricultural possibilities, and which makes this distinction important. Their sandy formation is usually covered with a growth of post oak. Its areal extent is not definable, owing to the absence of partings as above explained. The foregoing

blue dirt has no development south of Clark county, for the reason that the waters in that region were deeper, and because the beds above described are merely local littoral horizons.

The Koster "Joint Clays."—Continuing westward and geologically downward, the next horizon is found along the military road, in the gulches between its junction with the Mount Ida road, and the New Hope chapel, some two miles west of the junction. This horizon is best exposed in a ravine at the head of Bradshaw's creek, just west of Mr. Nicholas Koster's house on section 13, 7 S., 21 W., and across the road from the church. Here may be seen some fifty feet of yellow, calcareous clays, or "joint clays," as they are locally called, which are rich in the fossils of the overlying and underlying formations, as well as the lime which has resulted from their disintegration. These clays greatly resemble the *Exogyra ponderosa* marls above described, except that they have more clay and less lime. This horizon is possibly the northern and thinner edge of the great *Exogyra ponderosa* marls seen farther south.

The Big DeGray Horizon.—At Mr. Bridge's, about two hundred yards west of Mr. Koster's, the "joint clays" pass into a series of blue marls, similar in color to those above the clays, but having a much finer structure, and less sand, but more lime, mica, and, perhaps, glauconite. This is the beginning of a local littoral formation in which I have included all the strata between the Koster joint clays, and the undoubted paleozoic, upon which they can be seen resting in the bed of the Big DeGray creek near McCaulley's. The region between Bridge's and McCaulley's has but few outcrops; the country is densely wooded, and in the absence of topographic data the estimates of thickness are only approximations. This blue marl is full of fossils, the shell substance being beautifully preserved, but crumbling upon exposure. At McCaulley's (7 S., 21 W., center of section 1), however, near the west end of his fields, at the neighborhood cemetery, there is an outcrop of dark blue calcareous sandstone, coated with beautifully preserved fossil shells. As an illustration of the scarcity of outcrops, this one fragment was declared by people of the neighborhood, who

considered it a great curiosity, to be the only rock of the kind in the country, and it was only after long and careful search that some exposures of it were found *in situ*, about half a mile north of this one spot, in the lateral branches of the Big De-Gray creek. Here is a fine outcrop, consisting of occasional bands of hard siliceous rock, and alternating strata of blue marls, blue sands, etc. The rock is of a bright steel blue color upon fresh fracture, but externally, it has the appearance of a dark brown sand or "ironstone," and one would hardly suspect its true nature upon first examination. The fossils, which are the same species as those in the marls above, are beautifully preserved in local bands throughout the stone, so that large masses may show no signs of them, or, on the contrary, small slabs will show so many beautifully preserved fossils, that it is difficult to believe that they are a part of the harder rock. These fossils show as great a number of species as any near-shore fauna of the sea coast of today, and were it not for the occurrence of a few forms like *Inoceramus*, and the fact that they are found stratigraphically below cretaceous forms, one would believe them to be recent, or, at least, late tertiary.*

These fossils which are here so well preserved are of interest in that they establish beyond all doubt the continuity of

*I have recognized, in addition to several new forms, the following species, many of which range throughout the upper cretaceous series:

I.

<i>Pholadomya tippiana</i> ,	<i>Crassatella ripleyana</i> , Con.,
<i>Leptosolen buplicata</i> , Con.,	<i>Nucula percrassa</i> , Con.,
<i>Legumen ellipticus</i> , Con.,	<i>Anomia argenta</i> , Con.,
<i>Dosinia densata</i> , Con.,	<i>Pugnellus densatus</i> , Con.,
<i>Callista (Meretrix) tippiana</i> , Con.,	<i>Aporrhais decemlirata</i> , Con.,
<i>Papyridea bella</i> , Con.,	<i>Rimella ? curvileratus</i> , Con.,
<i>Cardium tippanum</i> , Con.,	<i>Conus canalis</i> , Con.,
<i>Cardium ripleyensis</i> , Con.,	<i>Pachycardium (Lævicardium) spillmani</i> , Con.,
<i>Drillia novemcosta</i> , Con.,	<i>Volutithes cretacea</i> , Con.,
<i>Pleurotoma ripleyana</i> , Con.,	<i>Chemnitzia interrupta</i> , Con.,
<i>Fusus novemliratus</i> , Con.,	<i>Trichopteris cancellaria</i> , Con.,
<i>Fusus bellaliratus</i> , Con.,	<i>Turritella tippiana</i> , Con., or
<i>Pyrifusus subdensatus</i> , Con.,	<i>Turritella altilis</i> , Con.,
<i>Rapa supraplicata</i> , Con.,	<i>Natica rechlabrum</i> , Con.,

the cretaceous formation in Arkansas with that of Mississippi upon the east and Texas on the south. Both faunally and lithologically they seem identical with beds which were once considered peculiar to a limited locality near Ripley, Tippah county,* and which have heretofore been reported from only one other locality, several hundred miles south, in Navarro county, Texas,† occurring in nodules at the top of the great development of *Exogyra ponderosa* marls of the series. These fossils reveal another important stratigraphic fact, and that is that the lithologic divisions of the cretaceous proposed by Dr. Hilgard for these uppermost beds do not have constant position, but are local horizons which vary with the circumstances of their deposition.

The DeGray beds are very local, and do not extend beyond Clear Springs in Clark county. They can be seen in many places resting upon the paleozoic, the rocks of which are very massive, hard, dark brown outside, pink and white internally on fracture. The marls of the overlying cretaceous near the contact with the paleozoic are full of small black siliceous pebbles and characteristic fossils.

*"This beautiful series of cretaceous forms seems to be very limited in geographical distribution, so far as our present knowledge extends. It is probably unknown as yet beyond the limits of Tippah county, which borders on Tennessee. No account has been given of such a group by the State Geologists of Tennessee or Alabama. Dr. Spillman informs me, 'the fossils you have now under examination, were found in the bluff of Owl creek, three miles north of the town of Ripley,' and he concurs in opinion with me that they might properly be named the 'Ripley group.' He also remarks that *Ammonites placenta* occurs in it with the shell preserved, and that in connection with the Ripley group, or in the same locality, are '*Exogyra costata*, *Gryphæa mutabilis*, *Ostrea plumosa*, *Natica petrosa*, *Nautilus dekayi*, etc., with the shell more or less preserved, in an argillo-calcareous marl,' but none of these species are contained in his collection sent me from Tippah county." *Journal of the Academy of Natural Sciences of Philadelphia*. Philadelphia; 1855-1858, Vol. III, Second Series, p. 323, Art. XX.—Observations on a group of Cretaceous Fossil Shells, found in Tippah county, Miss., with descriptions of fifty-six new species. By T. A. Conrad.

†See *Trans. St. Louis Academy of Natural Science*, March 18, 1861, and *Proc. Boston Society of Natural History*, September 4, 1861.

B.—THE CHALKY MARL BEDS.

4. *The Marlbrook-Columbus or Gryphæa vesicularis Chalk Marls.*—The Big Deciper beds seem to be underlain nearly everywhere exposed between Okolona and Saratoga by a white chalky marl containing a large percentage of clay, and decomposing readily under the influence of moisture. This horizon is especially marked by the occurrence of enormous oysters of the rugose ponderous variety of *Exogyra costata*, and the large variety of *Gryphæa vesicularis* (*Pycnodonta* of Conrad). These forms, which are not limited to it, however, occur by the millions throughout the extent of this horizon, especially along the Marlbrook-Columbus ridge.

The Arkansas, Louisiana and Texas railway makes a deep cut through this ridge three miles north of Washington, which gives an excellent section. In Clark county these rocks are exposed at Okolona, in the old fields southwest of town.

The arenaceous limestones of the Big Deciper bluff can be seen to graduate downward into these white, chalky marls, yellow, pale blue clays, and marls along the Big Deciper valley, as it traverses the Boseman farm, about two miles west of the Okolona road exposures. These marls contain from 25 to 75 per cent. of calcium carbonate. When freshly exposed and moist, they have a delicate blue tint, but when dry they become pure white. While these limestone beds have a great resemblance to the Rocky Comfort chalk, they are, in general, much more friable in structure, more argillaceous in composition and of a more yellow color. But its chief distinctions are in the association of the *Gryphæa vesicularis* and the *Exogyra ponderosa*, a variety of the *Exogyra costata*, which in company with the *Gryphæa vesicularis* lie upon the surface wherever the strata have weathered. They have frequently been gathered and used for paving, and burnt for lime.

This horizon is also characterized by numerous bones of saurians, and is the locality from which Drs. Koch and Leidy secured the Bromo-saurian bones described by the latter in the Proceedings of the Academy of Natural Sciences for 1854.

The only specimen of *Radiolites* seen by the writer in the Arkansas cretaceous was collected in this horizon near Saratoga.

There are also very thin sheets of shell breccia composed of fossil oysters (*Ostrea larva*), *Anomias*, sharks' teeth, and other fossil remains. After weathering for a short time in the presence of vegetable matter, these chalk marls turn first blue, then yellow, and finally, in the presence of vegetation, form a deep black soil, locally known as "black lands." From the wells in the valley of the Deciper creek, and the height of exposures on the hills, this horizon is supposed to be fully 200 feet thick along the Big Deciper. The marls are rich, having from 18 to 50 per cent. of lime, and are of great importance in the agricultural economy of the country.* Owing to the presence of lime the earthy material of these strata become friable on exposure to the atmosphere, often breaking into cubical fragments, from which fact, especially where they contain 30 per cent. of lime, they are locally called "joint clays." Boseman's plantation in Clark county is their most northern outcrop, and probably the northern terminus of the original Columbus-Marlbrook ridge. Southward from this point these marls increase in areal extent and thickness, and, were they not obscured by the overlying gravel in many places, would be the equivalent formation of the region. The "black lands" of Okolona in Clark county, of Ozan in Pike county, and those east and west of Washington and Columbus, and near Fulton, and those of Brownstown and of Ben Lomond, all belong to this and the underlying yellow marl horizons. Where the lime is at a minimum, the land is yellow and sticky, and is not always cultivated. The beds of this formation extend from eastward beneath the quaternary drift, but in places exposed as far as the Iron Mountain railway. The exposures occur only in ravines near Prescott, Hope and Fulton. They seem almost identical with the strata which Mr. Hilgard has described as

*See part on Economic Geology.

the "rotten limestone"* in Mississippi—at Blackland, in Tishomingo county, near the Tennessee line.†

Below these white marls, as seen at the northwest base of the Marlbrook-Columbus divide, there are other arenaceous beds, which may be identical with the second "blue dirt" of Clark county, described on p. 79, and it is at this horizon that the small creeks wear wide flood plains. Next below these sands is another one of the most marked horizons of the series. This is

5. *The Brownstown, or Yellow Exogyra Ponderosa Marls.*—

These beds consist of calcareous, lemon-colored clays, of great thickness and uniformity of character throughout their extent, containing from 20 to 40 per cent. of carbonate of lime, which appears to be foraminiferal or chalky rather than dissolved shell substance, and which causes the clays to have a friable, flocculent structure when exposed to the atmosphere. These clays occasionally become red by oxidation of the iron, as at Okolona, but more generally they preserve their yellow color. They are covered by a fine growth of hardwoods. Unlike the preceding horizons, they seem singularly devoid of fossils, except one species, and that is the large ponderous variety of *Exogyra costata*, which has here usually a more substantial and dark colored shell structure, and is somewhat flattened. These shells occur sparsely distributed throughout the clays. From the flocculent, fine-grained character of these clays, the absence of littoral fossils, and the presence of chalky carbonate of lime, they appear to be sediments which were deposited in waters of moderate depths between the limits of near shore and predominatingly foraminiferal life—an opinion which is strengthened by the pure chalks that underlie them, and by the vigorous molluscan fauna in the *Gryphæa vesicularis* marls above them.

*In the present report the use of the term "rotten limestone" cannot be accepted either as a lithologic or as a stratigraphic name, and for the reasons stated in pp. 68, 83 and 92 its abandonment is proposed.

†See Hilgard's Report on Agriculture and Geology of Mississippi, pp. 76-77, and Hilgard's Geological History of the Gulf of Mexico, American Journal of Science, December, 1871.

These are interior of the above described horizons, and outcrop along the coastward boarder of the plateau gravel, being entirely covered by the latter formation.

They are seen in small outcrops at the following places: beneath the gravel at Paraclifta, Sevier county; in the bed of Mine creek, one mile east of Nashville; one mile east of Hickory Creek Post-office; in the banks of the Ozan and along the road from Wallaceburg to the Little Missouri ford; on the Pike county scarp of the flood plane of the Little Missouri at the old military ford; at Senator Copeland's; at the Kelley place, and at a few other spots in southwest Pike county. They probably find their northern termination at Okolona or at Koster's in Clark county. At Ben Lomond and Brownstown, in southern Howard county, however, there are nearly two hundred feet of thickness and many square miles of these clays exposed in the slope of Little river valley between the great gravel plateau's scarp, some 315 feet above the river, and the top of the chalk bluff. This area was no doubt originally continuous with the one commencing on the east side of Mine creek, near Mineral Springs, and continuing interruptedly just interior of the Marlbrook-Columbus ridge northeasterly through the county.

At many places this horizon is marked by the deep cut ravines and washes, which at every rainfall carry away tons of valuable marl. Owing to this readiness of dissolution the topography of the country where this formation occurs is usually exceedingly rounded with numerous deep gulches and running streams, presenting a diversified landscape.

These marls increase in thickness southward in Texas, being over 1000 feet at Corsicana and at Austin. In that state they are the foundation of a large part of the great agricultural area known as the "black waxy prairie."

6. *The White Cliffs Chalk.*—Descending from the post-tertiary gravel capped plateau into the valley of Little river* the foregoing clay marls can be found resting upon, or changing into a great bed of the purest white chalk, at the bluffs of

Little river, section 35, 11 S., 29 W. These cliffs, which have long been a landmark of the region, are about 150 feet in height, perpendicular, and as white and almost as pure as the celebrated chalk cliffs of Dover, England. Their remoteness from the lines of travel is the probable explanation of their having so long been overlooked by American geologists.

The chalk of these cliffs scales off rapidly in great conchoidal flakes, and, owing to the irregularity of this process, its face instead of being a continuous plane, is composed of many acute and reentrant angles, resembling the bastions of a fortress. The summit of the cliff is covered with gravel, but measuring from the top of the hill a short distance from the margin, the present thickness of this chalk is found to be about 135 feet from the summit to the bed underlying it. This chalk has a low southeastern dip.

The regularity of this bed throughout its exposure—about one-fourth of a mile—and its reappearance a few miles to the east and across the Saline watershed, shows that it is not a local bed, but the remnant of a great and extensive horizon worn away by the denudation through tertiary and quaternary times of the deposits of the Red river embayment. From the summit of this bluff one looks out over broad lowlands to the south and east which form the drainage basins of Little and Red rivers, and over which this chalk bed once extended. These topographic features together with the overlying quaternary gravel beds and present disintegration speak most plainly of the great forces that have removed it.

This chalk is almost free from fossils, but indistinct impressions of *Camptonectes*, *Inoceramus*, *Baculites* and other forms, are occasionally found.

6. a *The White Cliffs Sub-Chalk*.—The basal thirty feet of the cliffs are composed of an impure chalk, composed of glauconite and arenaceous grains, cemented by a calcareous matrix. This is full of the characteristic upper cretaceous fossils, *Inoceramus barabini*, *Baculites ovatus*, *Exogyra costata*, etc.

This horizon is the lowest one of the upper cretaceous seen in Arkansas, for the whole region westward and south-

westward is again covered by the omnipresent quaternary, and when cretaceous strata again outcrop in the extreme southwest corner of the State, they are mostly of a lower horizon, although probably closely related to these.

The Morris Ferry Greensands.—There is an outcrop, however, which deserves special mention. This is at Morris's ferry on Little river, in the northern edge of Little River county. Here, near the low water line of the river, and covered by alluvial and quaternary deposits on every side, is a small outcrop of hard massive rock, extending up the river for about 100 feet, resembling very much in color and appearance an outcrop of dark green basalt. Upon closer examination, however, it is found to be composed of fine grains of greensand, calcite and siliceous sand. For miles around there is no evidence of its relation to the other cretaceous areas, except that the lower cretaceous (Comanche series) can be seen several miles further up the river and dipping in a direction which would probably carry them beneath these greensands. In Texas, however, where the cretaceous section is more conveniently exposed, there is no evidence of the intercalation of such greensand beds between the *Exogyra ponderosa* marls and the Rocky Comfort chalk, and hence for the present these greensands are assigned no position in the geologic scale.

THE ROCKY COMFORT CHALK.*

[Niobrara Group. Meek & Hayden (in part); Kreide. am Fusse des Hochlands, Roem. (in part); Austin Limestone, Shumard (in part); Dallas Limestone, Hill.]

Descending geologically, the marly strata and peculiar fossils of the upper cretaceous cease, and its basal continuation is concealed in Arkansas by the quaternary covered divide between Little and Red rivers. At Austin and other points in Texas it is succeeded by firmer and more uniform chalk strata, which outcrop beneath the quaternary so conspicuously in the town of Rocky Comfort, Little River county, forming the gently undulating topography of that village.

This is a continuation into Arkansas from Texas of a formation that has great development in that State, and which in a

*American Journal of Science, April, 1887, p. 298.

previous paper the writer called the "Dallas limestone." It is unique and one of the most widespread formations of the American cretaceous section, extending from Arkansas southward to Mexico, and if it is the upward continuation of the Niobrara beds of Kansas, as supposed, thence northward to British America, except where denuded from the central Texas region.

Like the other cretaceous formations in Arkansas, it has been extensively denuded, and its exposures covered by the deposits of gravel of later date, beneath which it outcrops in the extreme southwest corner of the State, in the slopes of Red river.

A few more outcrops of the formation occur along the medial slopes of the Red river valley in southwest Arkansas and southeast Indian Territory, composing the black lands of that region, but it is mostly covered by the continuation of the gravel plateau and by the Red river valley loess. It is best seen in the town of Rocky Comfort, where its dazzling white exposures are prominent objects of the landscape.

Although this chalk is merely a persistent horizon near the base of the upper cretaceous, of which it is the direct antecedent, it exhibits broad faunal, stratigraphic and lithologic differences that mark it as a most conspicuous horizon.*

The rock of this formation is a massive, nearly pure, white chalk, usually free from grit, and easily carved with a pocket knife. Under the microscope it exhibits a few calcite crystals, and particles of amorphous calcite, and innumerable foraminifera. The air-dried, indurated surfaces are white, but the subterranean mass has a bluish white color. The rock weathers in large conchoidal flakes, with an earthy fracture.

In composition it varies from 85-94 per cent. of calcium carbonate, the residue consisting of magnesia, silica, and a small percentage of ferric oxide, as can be seen from the fol-

*It is unfortunate that so little of this horizon extends into Arkansas, and that its contact with the overlying formations is here concealed. Since natural conditions do not always accord with political divisions, however, it is necessary, in order that this horizon be clearly understood, to make frequent allusions to the regions in which it is typically exposed.

lowing analyses of unselected specimens by the chemist of the Survey :

	Texas.	Rocky Comfort.
Calcium Carbonate.....	82.512	88.48
Silica and insoluble silicates.....	11.451	9.77
Ferric Oxide }	3.648	1.25
Alumina }		
Magnesia.....	1.189	trace

The thickness of this chalk at Rocky Comfort is over 500 feet, 100 feet of which can be seen at the surface, the remaining 400 feet having been penetrated by bored wells. So far as observed in Texas it averages the same thickness at Austin, Sherman and Dallas. It is of great uniformity throughout its massive thickness and extent, but it shows a few local differences in hardness, which are sometimes due to surface induration.

It so closely resembles some of the beds of the underlying Comanche, and of the overlying upper cretaceous, that, until recently, they have not been differentiated. Upon close examination, however, it is noticeable that the lower cretaceous beds, as seen where Little river crosses the Choctaw boundary, are distinctly stratified, and very much harder, and generally more or less crystallized from pressure, solution, and redeposition of the carbonate of lime in the chalk. The topography of the Rocky Comfort beds is also of a sharper and bolder type than that of the Comanche series, and is recognizable even at a distance. Above all it is distinguished by its softness and by its entirely different fossil remains. The Rocky Comfort beds are also distinguished from the other chalky beds of the upper cretaceous, by their greater firmness, different fossils, and by their higher percentage of calcium carbonate. With the exception of the White Cliff chalk, the other beds of the upper cretaceous seldom contain more than 50 per cent. of calcium carbonate, the average being 20 and 40 per cent. The Rocky Comfort beds are also the only ones of considerable extent which have these peculiarities, those at White Cliff being the only ones known to bear even a partial resemblance to them.

The rock is too soft for building purposes in the humid regions of Arkansas, owing to the readiness with which it decomposes on exposure, a fact, however, which makes it of the greatest value in agricultural economy, for it is by the decomposition of the chalk that much of the rich, black, calcareous prairie lands of northern-central Texas,* and of the vicinity of Rocky Comfort in Arkansas, are formed, the chalk passing by imperceptible transitions into this soil. In the arid region southwest of Austin, however, this chalk becomes hard upon exposure, and is sometimes indurated by igneous contacts, so that it makes a good building material in that climate.

Although this Rocky Comfort deposit is by far the most clearly exposed and economically important of the geologic series in Texas, it is a remarkable fact that it has never, until lately, been clearly diagnosed and separated from the vastly different overlying upper cretaceous and underlying Comanche series. It is true that it has been partially described by Roemer, Shumard and Loughridge, but none of them differentiated or so described it that it is recognizable. Roemer included it with the overlying beds of the *Exogyra costata* series, and the underlying fish shales, in his general group of the cretaceous at the foot of the highlands. Shumard described it under the name of the "Austin limestone," but, in addition to copying Roemer's diagnosis, placed it so out of position in his section that it seems improbable that he could have had the least intimation of its true position. Dr. Loughridge includes under the general term of "rotten limestone" all the cretaceous limestones of his central prairie region of Texas. Neither of these authorities discovered the fact that it is entirely different from the lower Texas cretaceous as seen at Cerro Gordo, in Arkansas, while they all included in their descriptions some of the features of the adjacent formations.

The writer has also contributed his share to this confusion by asserting it to be the "rotten limestone" of the other Gulf

*These black lime lands should not be confused with those of *Exogyra ponderosa* marls and upper horizons, or with those of the upper Comanche series. See discussion on Agricultural Geology in Part II.

states (American Journal of Science, April, 1887, p. 297), when in reality it is probably more chalky, and separated from those beds by the immense development of *Exogyra ponderosa* marls, and it does not occur in Alabama at all. The statement of their identity is here retracted, together with all use of the words "rotten limestone" as a stratigraphic or lithologic term.*

To avoid further confusion the following definition of this horizon is offered: The Rocky Comfort beds include the massive, chalky strata as seen in the town of Rocky Comfort, Ark., overlying the fish bearing marls, and underlying the yellow *Exogyra ponderosa* marls as seen along the valley of the Colorado river in Austin, Texas, from the public bridge to a point two miles east of the city, and the extension of these beds north and south of that city into Arkansas and Texas respectively. The characteristic fossils of this formation are the *Radiolites austinensis*, Shum., the giant *Inoceramus*† (sp. ind.), and the little oyster which occurs in such quantities and variety, and which may be the young of *Exogyra costata*, called *Ostrea læviscula*, Roemer, *Nautilus dekayi*, and other forms, all of which except the *Ostrea* are poorly preserved as casts, and seldom recognizable except after much weathering.

Dr. B. F. Shumard mentions the following species, that accompany his Austin limestone, but it has been shown that he includes in this horizon some specimens from the overlying beds: *Inoceramus biformis*, *Gryphæa vesicularis*, *Exogyra costata*, *Ostrea vesicularis*, *O. anomiaformis*, *Arca vulgaris*, *Radiolites austinensis*, *Nautilus dekayi* (?), *Baculites anceps*, *Helioceras*, *Cassidulus æquoreus*, *Hemiaster parastatus* and the scales and teeth of fishes. The last mentioned vertebrate forms belong to the shales, and underlie this chalk in Texas.

The writer must confess that, in his studies of this horizon in Texas, he has not found either *Gryphæa vesicularis* or any of its accompanying varieties in this horizon unless *O. læviscula* be its young. The characteristic fossils as he has observed

*For summary of geologic knowledge of this formation, see American Journal of Science, April and October, 1887; and Bulletin 45, U. S. Geological Survey.

†Compare *I. vanuxemi* and *I. balchii*, M. & H.

them are *Radiolites austinensis*, *Inoceramus "biformis," Exogyra ponderosa*, *Ostrea laeviuscula*, *Baculites anceps* and other well marked but undetermined species of *Inoceramus*, *Pecten*, *Spondylus*, etc.

Dr. Ferd. Roemer, in his list of fossils from the cretaceous at the foot of the highlands, included a few forms that we know now must have been washed down from the lower cretaceous formation which is exposed farther up the river.

The fauna partially resembles that of the vaguely defined "Tombigbee Sands," of the Mississippi and Alabama region, but the writer believes this horizon to be below that of those states, and below the Niobrara and Fort Pierre of Meek and Hayden. The rock mass has no lithologic resemblance to the Alabama-Mississippi beds, however, though very close paleontologic similarity.

The Rocky Comfort beds have no representative in New Jersey, the upper beds in that state being later, and a long hiatus having ensued there between the lowest and the uppermost American cretaceous. Neither have they been positively identified in the Alabama-Mississippi region.

Although I was unable, owing to the presence of the overlying debris, to find in Arkansas the actual contact between Rocky Comfort chalk and the overlying upper cretaceous, I have often seen it east of Dallas and Austin, Texas. It is certain that the Rocky Comfort beds do not extend far to the north of Rocky Comfort, and that they do not overlap the old paleozoic continent anywhere in Arkansas.

The western border of this chalk commences a few miles west of the southwest corner of the State of Arkansas, in Indian Territory, crossing Red river (the exposures continuing up the south side of the valley of that stream to the north of Sherman where it deflects southward), passing near Whitesboro, Sherman, McKinney, Dallas, Hillsboro, Waco, Belton, Austin, San Antonio and Spofford's Junction, Texas, beyond which it bends northward, appearing in the disturbed mountains in the vicinity of El Paso and the new Mexican realm, and again in No Man's Land, Kansas, Nebraska and Colorado, where it is

closely related and probably identical with the Niobrara chalk of Meek and Hayden.

A great portion of the former extent of this chalk has been destroyed by erosion, and its western border in central Texas is now receding eastward under the influence of excessive atmospheric decomposition and denudation. From Austin to San Antonio it is more stable, but west of the latter place erosion again becomes great. That the whole group once continued far to the west, and perhaps entirely across the state is not at all improbable.

The characteristic topographic and physical features of this formation as seen at Rocky Comfort, such as the gently undulating topography, the white crumbling exposures, the intense blackness of the soil, are so nearly identical with those of the same formation in Texas, that they are indistinguishable.

In Texas the base of this chalk rests nearly everywhere directly upon the Eagle Ford (Colorado) shales, as near Dallas, Austin and San Antonio. It is most probable that the Ouachita mountain system mentioned on p. 10 was also the limit of this sedimentation.*

*Since the above was written, the *Exogyra costata*, var., *ponderosa*, has been found at the very base of the Rocky Comfort division at Onion creek, Texas, thus establishing beyond question the position of these beds as a part of the upper cretaceous or *Exogyra costata* series.

CHAPTER IX.

GENERAL CONCLUSIONS ON THE UPPER CRETACEOUS OR EXO- GYRA COSTATA SERIES.

The upper cretaceous or *Exogyra costata* series, including all the cretaceous strata in Arkansas from the base of the Rocky Comfort chalk upward, and in Texas from the base of the Lower Cross Timber sands, is continuous and unbroken, both stratigraphically and faunally. In structure it is, with few exceptions, marly and unconsolidated, and in composition it varies from sands to clays, from clays to chalk, and from a pure foraminiferal chalk at its base through a thousand feet to arenaceous beds at its top, all of which indicates deposition at both great and at moderate depths, mostly beyond littoral influences. Although exhibiting, at first sight, great lithologic extremes of color, structure and texture, the sediments composing the strata are continuous and unbroken in deposition, and merge gradually one into another, and are connected from top to bottom by a unique, characteristic and unmistakable fauna of marine mollusca. The variation in color, texture and structure of the sediments is due to the varying condition of deposition during the period of great subsidence which it records, such as depth and distance from land, conditions exactly identical with those now existing in littoral and infralittoral depths of the ocean, as has been shown by recent sea investigations; and to subsequent chemical changes of the organically derived minerals, such as the molluscan and foraminiferous carbonate of lime, greensand and compounds of iron. The minerals which have taken no part in organic changes, such as amorphous carbonate of lime and silica, seldom exhibit much change. In fact, both stratigraphic and lithologic evidence attest the unity of the sediments of this series of beds and their gradual change from sands through clays into pure chalks at the base, and from chalks to arena-

ceous shales at the top. This fact is also specially proven by the following analyses of specimens taken from the various horizons, which show the decreasing proportions of carbonate of lime in ascending order:

*Table of Analyses of Upper Cretaceous Chalks, Chalk Marls and Calcareous Sands from Arkansas, Showing Decreasing Proportions of Foraminiferous Chalk in Ascending Strati-graphic Order.**

	CALCIUM CARBONATE	MAGNESIUM CARBONATE	INSOLUBLES.
1. High Bluff sands	6.59		
2. Dark colored marl, Okolona.....	22.51	2.00	58.07
3. Chalky <i>Gryphaea vesicularis</i> marl, Hearne P. O	33.17		39.04
4. <i>Exogyra ponderosa</i> chalk marl, east of Brownstown	46.73	1.50	41.72
5. Chalk, White Cliffs of Little river	94.18	1.37	3.49
6. Chalk (Niobrara?) Rocky Comfort, Ark.....	88.48		9.77
7. Eagle Ford Shales (calcareous clays)			
8. Lower Cross Timber sands	trace.		85.00

It is almost everywhere evident that the soft unconsolidated strata of this series have been greatly eroded by atmospheric action, and denuded by two or more great marine inundations which took place, one at the beginning of the tertiary, the other at the close of that period or during the quaternary. It is evident, therefore, that the existing strata represent but a small fraction of their former thickness and extent. In Texas indeed nearly all the upper arenaceous horizons of the upper cretaceous were removed before the tertiary sediments were laid down.

No measurement of the original thickness of the upper cretaceous can be given, but judging from existing fragmentary outcrops, over 1500 feet remain. That hundreds of feet of the uppermost portions of these beds have been removed, can be seen also in the post-cretaceous debris. Two thousand feet would be a low estimate of the original thickness of the upper cretaceous strata in Arkansas and northern Texas.

*Analyses by the Geological Survey of Arkansas.

CHAPTER X.

THE RELATION OF THE UPPER CRETACEOUS OF ARKANSAS TO THAT OF OTHER AREAS.

I. *Relation to the Texas Region.*

It must be apparent that the upper cretaceous formation of Arkansas is the direct northeastern termination of the great development of that series of rocks in Texas, and nearly every definite stage of it here is represented in that state. The wide erosion of the Red river valley, and the accompanying debris which separates the two states is no greater than the basin of the Little Missouri river that separates the exposures of Clark county from those of Pike. The upper or arenaceous beds of the *Exogyra costata* series, or uppermost beds of the cretaceous group, have been studied very little in Texas, owing to the fact that they are inconspicuous in comparison to the enormous development of the lower chalky beds and the underlying middle and lower cretaceous, and have been eroded in most places by the tertiary and quaternary waters. The upper beds occupy only a narrow band along its eastern exposure of the cretaceous, and they have suffered even greater denudation in that state than in Arkansas. The writer, however, has seen the yellow lime *Exogyra ponderosa* marls of the upper cretaceous resting directly upon the firmer Rocky Comfort chalk as far south as Austin, Texas, where, four miles east of that city, these marls present identically the same facies as at Okolona and other points in Arkansas. In 1852 Dr. Ferdinand Roemer described these lime marls, from three miles east of New Braunfels, as resting upon the harder chalk of the Austin (Rocky Comfort) limestone,* and clearly showed their extent from Austin to an undetermined point beyond San Antonio, and figured the characteristic ponderous variety of the *Exogyra costata* from them for the first time. There is

*Kreide von Texas, pp. 41, 71.

little reason to doubt that this marl, with the big oyster, continues without interruption in its deposition directly upon the Rocky Comfort chalk, from where it is last seen in Arkansas to near the Rio Grande. Fragments of the arenaceous upper beds or high bluff sands and their accompanying more littoral fauna also extend along a very narrow strip into Texas as far south as Corsicana, and perhaps much beyond, the metamorphosed glauconitic beds of the lower Rio Grande, as described by Schutt,* having much resemblance to them.

The writer thinks there can be little doubt of the identity of these Arkansas beds and those of the Navarro (Corsicana) beds† of the Texas section of the upper cretaceous, the Navarro fauna especially resembling that found on the Big DeGray creek in Clark county. March 18, 1861, Dr. B. F. Shumard communicated some of the results of his investigation upon the cretaceous formations of Texas, to the St. Louis Academy of Science. He stated, that aided by his brother, Dr. George G. Shumard, Dr. W. P. Riddell and other members of the Texas Geological Survey, he had made extensive collections of fossils‡ from beds not previously recognized in that state, and which appear to correspond in age with the Ripley

*Mexican Boundary Survey, vol. 1.

†Dr R. H. Loughridge also reports them from Terrell, Texas. He says: "In the railroad cut I observed an outcrop of a hard, fossiliferous limestone, resembling in character that which occurs at Lumpkin, in Stewart county, Georgia. Among the fossils recognized were *Turritella*, *Exogyra*, *Belemnites* and *Pachycardium ripleyensis*." United States 10th Census Report, vol. 5, p. 18.

‡It is a remarkable fact that under the reconnaissance made in east Texas and Arkansas, and in the old method of searching for fossils, that the predominating soft strata, such as the sands and clays of the High bluff and of the Camden series, as well as whatever traces of fossils they may have contained, have been utterly ignored, and only the unusual features, such as the hard rock layers and well preserved fossils have been studied. As these parts constitute only a very small fraction of the entire formations and are not representative, of course no very intelligible idea could be formed of the whole from them. The older methods of collecting only the best fossils from well preserved beds and ignoring the poorly preserved traces of them in the alternating or intervening strata, and sending them away for stratigraphic and paleontologic determination, has been the cause of much confusion in the study of the mesozoic and tertiary geology of the south.

group of Tippah county, Miss., and Eufala, Ala. The fossils were found in sepataria, imbedded in blue and grayish yellow arenaceous clays, and occur in an elegant state of preservation, the iridescent hues of the nacre being preserved as perfectly as in recent shells. Dr. Shumard had been able to recognize in the Navarro beds about twenty species of the Ripley group (upper beds) of Alabama, Mississippi and Arkansas. Among these he mentioned *Nautilus dekayi*, *Baculites tippaensis*, *B. spillmani*, *Purpura cancelaria*, *Rapa supraplicata*, *Ficus subdensatus*, *Pleurotoma tippa*, *Cardium spillmani*, *Legumen elliptica* and *Exogyra costata*. On September 4th of the same year, in a paper presented before the Boston Society of Natural History, he said: "The precise stratigraphical position of the Navarro county beds, with reference to the other members of the cretaceous in Texas, has not been certainly determined, though I am inclined to believe their position is above the Austin limestone (Rocky Comfort chalk) of the Texas section."

My own observations in Arkansas and Texas, as well as a careful comparison of the collections of the authorities above mentioned, establishes this identity of the Arkansas and Texas beds, and shows, notwithstanding the surface obscurity, their direct geographic continuity.

The former areal extent of the series as a whole over northern Texas, between its present western border and the eastern scarp of the staked plains proper, has been entirely denuded; but its continuity across the southern end of the state from San Antonio to the Franklin Mountains west of El Paso, can still be demonstrated by the many extensive areas, and the highly metamorphosed fragmentary strata of the trans-Pecos region, all of which are accompanied by the typical fossils. The identity and continuity of the subdivisions west of San Antonio have not been determined, however, but the writer has found the *Exogyra costata* bed in many places in that region as far west as the mountains on the Texas-Mexican line near El Paso.

Concerning the extent of the basal upper cretaceous series,

or the Rocky Comfort chalk from Arkansas into Texas, it can be said that it is continuous and unmistakable, and that it is at the same horizon as the chalky rock that underlies all of northern and central Texas east of the Missouri Pacific railway. This is especially well displayed along its western edge in Grayson, Collin, Fannin, Dallas, Hill, Navarro, McLennar, Bell, Williamson, Travis, Hages, Guadalupe, Bexar and Maverick counties.

II. *Relations to the Northwestern United States.*—The easternmost beds of the main body of littoral Fox Hills and Fort Pierre beds of Meek and Hayden in Colorado and Wyoming, which are the uppermost marine beds of the northwestern American cretaceous, are separated from the westernmost beds of the Gulf States upper cretaceous by many hundred miles, owing either to the destructive denudation of post cretaceous times, or to the fact that a land barrier existed between them during the time of their deposition. If such a barrier existed north of the Indian Territory mountain system, as it probably did, we find in the lower Rio Grande, or Eagle Pass region of Texas, evidence that the characteristic beds of the two areas unite. That there are many differences between the extremes of the two formations in Arkansas and in Colorado, both lithologically and faunally, is quite apparent. This difference consists in the northwestern beds being usually more consolidated, often from igneous metamorphic action, and in the absence therefrom of *Exogyra costata*, the fossil for which the series is named in Arkansas. These differences can be reconciled, however, when we consider the metamorphism that the former region has undergone, and the fact that its sediments were deposited in a shallowing sea, while in Arkansas much deeper conditions prevailed. In the near shore *Gasteropoda*,* and the nomadic *Cephalopoda* of the

*The characteristic *Ostreida*, *Echinodermata*, and bivalves of the Arkansas beds are but poorly represented in the northwest, but there are many points of identity between the *Cephalopoda* and *Gasteropoda* of the Arkansas and Fox hills beds. As shown on page 63, the Laramie fauna is entirely missing in Arkansas, although its flora may be represented in the Camden series.

two regions, there is every resemblance. In fact the *Exogyra costata*, a deep water form, is never found in the Big DeGray littoral deposits of Arkansas, but only in comparatively deeper sediments, hence, the conclusion that the Fox Hills and Pierre beds of Meek and Hayden in the northwest represent shallower marine or inland conditions of the upper cretaceous of Arkansas, and, in their upper beds, even later strata which, if deposited in Arkansas, have been eroded.

Concerning the lower beds of the upper cretaceous there can be little doubt of their identity with the sands, clays and chalky sediments of Nebraska, Kansas and Colorado, known as the Dakota, Benton, and Niobrara beds, although their direct continuity is also disturbed by the Indian Territory mountain system, and by the great post-tertiary denudations. Both lithologically and faunally there is great resemblance between the chalky beds of these divisions in Arkansas, Texas, Kansas and Colorado. Especially is this resemblance marked in the peculiar *Inocerami*, *Radiolites*, *Nautili*, and in many of the small *Ostreidæ*, which, in the opinion of the writer, are simply the young of the *Exogyra costata* and *Gryphæa vesicularis* of the upper beds.

These great chalky deposits, which were once continuous from Arkansas around the western end of the Indian Territory mountain system, no doubt mark the profoundest subsidence of all mesozoic time, and were the deep sea sediments of the western Atlantic which had their synchronous continuation upon the eastern, or European side.

No representative of the Eagle Ford shales of Texas and Dakota littoral beds which mark the base or beginning of the upper cretaceous in the northwest are visible in Arkansas. They are no doubt the littoral borders of the continental area which must have existed in the region now occupied by the greatly reduced remnant of the Arkansas-Indian Territory mountain region.

III. *Relations to the Mississippi-Alabama Region.*—The relations of the Arkansas area to those of the region east of the Mississippi are obvious, but the direct continuity of the expo-

tures is obscured by the overlying tertiary and quaternary, and hence these relations must be established on comparative evidence.

The upper beds of the upper cretaceous, above the Rocky Comfort chalk beds, are identical in formation with the upper cretaceous of Alabama, Mississippi and Tennessee, comprising the horizons above the Eutaw, as described by Dr. Hilgard under the names of Ripley, the "Rotton Limestone Group," and the Tombigbee Sands, and also with certain beds in New Jersey. to be mentioned further on. Not only are they identical in age, but also in similarity and continuity of deposition, and were it not for the later erosions and the superimposed beds of tertiary and quaternary, and for the alluvial deposits of the Mississippi river, which have so obliterated the former geographic distribution of these beds, they could be seen to extend continuously from one state to the other.

This fact is proven in the identity of every generic character, chemical, lithologic, stratigraphic, and paleontologic; the differences between the outcrops of the two states being no greater than differences found and in close proximity in the strata of the same state, such as the difference between the outcrops of the High Bluff formation at Arkadelphia and the Nacotoch bluff of Clark county, differences as great as those between the same formation in Arkansas and Mississippi.*

*As I have already shown, Dr. Hilgard's classification of the strata of Mississippi into "groups," is not now in accord with the accepted definition of that ambiguous word. Dr. Hilgard's valuable writings show throughout that he meant by "group" one of the smaller geologic subdivisions, or what is expressed here by the word "beds" or horizon.

Dr. Hilgard does not expressly state that in Mississippi there is a perfect stratigraphic continuity between his various groups, but in two places in his report he shows this to be the case. On page 61 of his *Agriculture and Geology of Mississippi* he states that the "Tombigbee sands are very unequally developed in different localities, and apparently subordinate to the 'rotten limestone,' into which it shows many lithologic transitions, and many of whose fossils it shares." On page 83 he says that the "rotten limestone shows a paleontological as well as lithological transition into the Ripley group." These facts, confirmed by the writer's observations in Mississippi, destroy the estimated value of these formations there as separate groups, and show that in Mississippi, as well as in Arkansas, the strata constitute but

If the lower and principal beds of the Ripley "group," as given by Dr. Hilgard in his report (pp. 83-85), vary in lithologic character from the generality of strata of the Washington sands, and its subdivisions, as I have observed them at various places in southwest Arkansas, it cannot be detected. This lithologic and stratigraphic identity is made more certain by the identity of arrangement and quality of the constituents of the strata of the Arkansas beds with those of similar horizons in Mississippi, as determined by chemical analyses made by the respective state surveys.

The same can be said of the analogy between the "rotten limestone group" of Dr. Hilgard in Mississippi, and the upper *Gryphæa vesicularis* horizon of the *Exogyra ponderosa* marls of Arkansas and Texas. The Tombigbee sands, or basal upper cretaceous of the Mississippi section, however, while presenting a slight paleontologic resemblance to the lower or Rocky Comfort beds of Arkansas and Texas, have no lithologic resemblance to them whatever, the beds of the former being arenaceous instead of chalky. In fact, the Tombigbee sands can only be the slight eastern littorals of the constantly increasing western thickness of the lower beds of the upper cretaceous, as seen in the Rocky Comfort and Niobrara chalks of the West.

The so-called "Eutaw group" of Dr. Hilgard ("lower cretaceous of Tuomey") is conceded by Dr. Hilgard and later authors* to belong to an entirely different and older series than the upper cretaceous.

one continuous formation. It is only necessary to glance at Hilgard's list of fossils to see that there is even less ground for faunal than for stratigraphic demarkation, and to confirm fully the position that there is no logical ground for giving any of these subdivisions higher positions than horizons. It should also be understood that there are minor points about the Mississippi strata which the writer cannot interpret exactly until he has made as long and thorough a personal study of the strata there as he has made of the cretaceous of Arkansas and Texas.

Dr. Hilgard's work, which stands forth preeminently as one of the best contributions of geologic data in the country, and which is today the foundation of the Gulf States geology, is necessarily lacking in classification and generalization.

*On the Tertiary and Cretaceous Strata of Tuscaloosa, Tombigbee, and Alabama Rivers, by Eugene A. Smith and Lawrence C. Johnson.

In comparing the upper cretaceous series of the Arkansas-Texas region, as a whole, with that of the Mississippi-Alabama region, it can be said that the post-cretaceous denudations of the former region have removed in most places the uppermost cretaceous strata, and that the great development of the basal portion of the upper cretaceous, as represented by the great chalk beds, is wanting in the latter, except where feebly represented by the fauna of the Tombigbee sands. In Mississippi the upper cretaceous rests upon the lower pre-cretaceous (Tuscaloosa) and on the paleozoic; in Arkansas and Texas the upper cretaceous rests mostly upon a great development of the middle and lower cretaceous which is unknown east of the Mississippi.

IV. Relations to the New Jersey Area.—Owing to the great hiatus between the exposures of the upper cretaceous in Arkansas and those of the New Jersey regions, no exact stratigraphic continuity between them can, at present, be established. Certain paleontologic and structural resemblances, however, give strong evidence of their continuity.

The lower portion of the upper cretaceous in Arkansas and Mississippi, although in general composed of similar unconsolidated marly beds, do not exactly agree in detail with those of New Jersey. The rotten lime, or *Exogyra ponderosa* marls, have no lithologic equivalents in that state.

The rich greensand beds of New Jersey, which occur in several beds, although greatly resembling those of the South, have no positive stratigraphic identity with them, except that both belong to the same paleontologic horizon of the upper cretaceous, and both have similar structural features. The relations between the two areas at present must be determined entirely upon paleontologic evidence. In this connection it may be remarked that as exhaustive collections or studies of the Arkansas strata have not been made as of the New Jersey strata, many forms that now appear to be missing may be discovered by future research.

Of the New Jersey fauna none of the *Brachiopoda* have been found in Arkansas, and of the characteristic *Belemnitella*

mucronata, also reported from Alabama and Texas, only a single fragment has been found.

Of the principal *Ammonite* forms, the *Baculites* are common to New Jersey and the Arkansas area. The *Ammonites placenta*ceras, Meek, so common to New Jersey and to other cretaceous areas, has not been seen in Arkansas. The arrangement and literature of the *Gasteropoda* are not in a state that allow close comparison of these; but, thanks to the recent publication of Mr. R. P. Whitfield's *Brachiopoda and Lamelibranchiata of the Raritan Clays and Greensand Marls of New Jersey*,* we are enabled to make close comparison of the bivalves. The principal characteristic forms are common to both the *Exogyra costata* series of Arkansas and to the lower marl beds of New Jersey.†

None of these forms, according to Mr. Whitfield, except the *Gryphæa vesicularis*, occur in New Jersey in other than the lower marl bed; while in Alabama, Mississippi and Arkansas they characterize the entire upper cretaceous or *Exogyra costata* series, and until better evidence is obtained we must consider the upper *Exogyra costata* beds of Arkansas and the lower marl bed of New Jersey as equivalents and parts of the same great formation that was being deposited off the Atlantic coast from Texas to New York during the late cretaceous time. The lower chalky beds of Arkansas below the horizon of the Washington greensands are unrepresented in New Jersey. The absence from the south and southwest of representatives of the fauna of the middle marl beds of New Jersey strengthens the stratigraphic evidence of the tertiary denudation of the southern beds.

*Washington, D. C., United States Geological Survey, 1885.

†These are the *Exogyra costata*, Say; *Exogyra costata* var. *pondorosa*, *Gryphæa vesicularis*, Lamck., including all the varieties, such as *Pycnodonta* of Conrad; *Gryphæostræ vomer*, Morton and *G. convexa*; and the narrow form of *G. convexa*; the *Anomia argenta*, which is described in the New Jersey report under three specific names; *Pecten* (*Camptonectes*?) *simplicum*, Con. *Neitheia quinquecostata*, Lamck., *Idonearca tippiana*, Conrad; *Trigonia eufalensis*, Gabb; *Inoceramus sagensis*, Owen; *Inoceramus barabini*, Morton; *Cardium spillmani*, Con.; *Panopæa decisa*, Conrad.

General Relations to Other Regions.—It is now evident that the various horizons of the Arkansas upper cretaceous series form a continuous paleontologic and sedimental formation. It embraces nearly all the horizons of the uppermost of the two grand divisions of the marine cretaceous of the United States. This formation extends from the Dakota sandstone of the northwest to the middle marl beds of New Jersey inclusive, which collectively may be termed the upper division of the American cretaceous—the Comanche series of Texas constituting the lower division. The fauna of the Arkansas-Texas section, however, reveals the fact that while the upper cretaceous series in Arkansas embraces most of this upper grand division, the very uppermost layers (represented in the middle marls of New Jersey, the uppermost clays of the Ripley [Mississippi] beds, and the transitional sub-Laramie portion of the Fox Hills of the northwest) have probably been removed by tertiary and quaternary erosions, while the extreme basal layers (from the Lower Cross Timber group of Texas* to the base of the Rocky Comfort Chalk, especially the Denison clays, the Eagle Ford shales, and the horizon of *Ostrea bellaplicata*, Shum.) are either missing or obscured.

The conclusion has been reached by every observer who has studied these upper cretaceous beds of New Jersey, Alabama, Texas or the northwest, as grouped in this paper under the name of the upper cretaceous, or *Exogyra costata* series, that collectively they are the equivalent of the upper cretaceous of Europe.†

*See Geology and Topography of Cross Timbers of Texas, American Journal of Science, April, 1881.

†Sir Charles Lyell expressed the opinion that the fossils of the New Jersey cretaceous beds, of which this division is the equivalent, agree on the whole most nearly with those of the upper European series from the Maestricht beds to the Gault, inclusive. In his "Cours Elementaire de Paleontologie," Alcide d'Orbigny refers the New Jersey beds as well as those of Nebraska (Upper Missouri), Arkansas, Texas (Roemer's classification) and Alabama, all to the Senonian, the equivalent of the white chalk and the Maestricht beds of the old world.

Pictet, in his "Traite de Paleontologie," also refers most, if not all, of the New Jersey cretaceous fossils to the era of the white chalk of Europe. See Cretaceous Paleontology, Meek, pp. xliii-xlvii.

These upper cretaceous beds, representing as they do the sediments of the western side of the Atlantic ocean, cannot but have some relation to the beds of Europe upon the other side, and relations which, from the very continuity of similar physical conditions in the same ocean, must be in accord with, and not contrary to, modern geologic laws. Messrs. Lyell, Meek, Marcou and others have long since demonstrated the paleontologic similarity of the strata which are here classified as the upper cretaceous to those of the chalk or upper cretaceous of Europe. The writer's investigations not only confirm these opinions, but show much more intimate stratigraphic similarity than has hitherto been supposed to exist.

A careful comparison of the cretaceous fauna of the eastern United States with that of western Europe will show that the large majority of species common to both regions are much more closely related to the basal than to the upper portion of the chalk, a fact which strengthens the evidence of the denudation of the uppermost horizons of the upper cretaceous in Arkansas. While not at all endeavoring to establish exact synchronism of minute horizons, the writer has shown much closer relations between these American formations and those on the opposite side of the Atlantic than the accepted canons of American geology allow. This has not been done to satisfy any preconceived hypothesis, but solely because the geologic facts of this great southwest region admit of no other conclusion, and the fact that the same generic similarity of trans-Atlantic infra-littoral sediments existing at present have existed in the past. In fact these theories of non-correlation have originated entirely among geologists who have never seen these rocks. This doctrine is in accordance with every modern biologic and stratigraphic law, and its truth is here demonstrated beyond cavil. The rocks of this southwest region themselves show that in the generic similarity of the marine cretaceous sediments on both sides of the Atlantic, from the Wealden to the chalk, there has been no violation in favor of America of the great laws of marine life and sedimentation.

With sediments other than those formed in the open Atlantic basin, no correlation can be attempted.

The history recorded in this upper division of the American cretaceous is that of a slow and profound subsidence, culminating in the Niobrara or Rocky Comfort chalk, followed by a slow but gradual emergence until the post-cretaceous land epoch. During this land epoch, and in the subsequent subsidence of early tertiary time, the upper bed of the cretaceous sediments were greatly but unequally eroded.

CHAPTER XI.

THE LOWER CRETACEOUS OR COMANCHE SERIES.

Washita Division.

Fredricksburg Division.

Trinity Division.

Of the cretaceous strata thus far described, all belong to the upper division of the American system, and show an unbroken continuity, as is indicated by the transitional successions of its sediments and by the fossils they contain. Beneath this division there is another great series of cretaceous rocks, entirely different in its faunal and lithologic characters, not a single fossil having yet been found common to the two divisions. Not only is there a complete faunal break, but in Texas there is a marked nonconformity in deposition. At Austin, the slightly dipping upper cretaceous (*Exogyra costata* series) is seen deposited upon the highly disturbed beds of the lower cretaceous.* This unconformity also denotes a considerable land epoch which must have intervened between the two formations.

The beds of the lower cretaceous formation have an immense development in Texas, beyond the western boundary of the Rocky Comfort chalk, and extend into Arkansas from the Indian Territory. They are exposed in the chasm of Little river, occupying the country immediately adjacent to the State line, from Ultima Thule southward to within a few miles of Red river. Like all the other mesozoic formations in this State, its areal extent and partings are covered by the great quaternary plateau and its transported gravel, or concealed by vegetation. At the point where the boundary road crosses Little river, and up the eroded valley of that stream for many

*For the convenience of the reader the writer has appended the typical section of the Texas cretaceous as published by him in the American Journal of Science for April, 1887.

miles into the Indian Territory, there are fine exposures of massive limestones and clays belonging to this lower cretaceous or Comanche series. These beds are divisible into at least three distinct horizons.

The Washita Division.—The uppermost is composed of pale and yellowish green clay marls, occupying the upper slopes of the high divides. These crop out beneath the gravel and constitute the poor clay surface formation south of the village of Cerro Gordo, one and one-half miles south of the river, and 200 feet above it, where wells have been dug in it to the depth of 100 feet. They contain only one fossil, so far as a hasty examination could disclose, and that is the naviate variety of *Gryphæa pitcheri*, Morton, as figured by Owen on Plate VII,* figure 6 of his second report. These green clays constitute the formation underlying the poor lands from Cerro Gordo to within six miles of Rocky Comfort, and extending eastward to Cane creek. So similar are they in composition, color and accompanying fossils to those of Texas,† especially as seen in Shoal creek, in the City of Austin, that some four hundred miles distant and at intervening points, the great uniformity of the comparatively deep sea conditions under which they were deposited is apparent. These marly clays rest upon massive, semi-crystalline limestones, and *Gryphæa pitcheri* breccia, in strata of from one to five feet in thickness, forming the banks and canyons of the river for some two hundred feet in height, and containing *Gryphæa pitcheri*, Morton, *Requienia (Caprotina)*, and other fossils of the lithologic horizon of the Comanche series, which Dr. B.F. Shumard described as the "Caprina limestone," and which is about midway between the more fossiliferous Comanche Peak and Washita horizon.

The Fredericksburg Division.—Four miles down the river from Cerro Gordo, at Coulter's place, in section 4, on

*For a complete statement of the present knowledge of this series, see American Journal of Science for January, 1887, pp. —; American Naturalist, February 1887, April and October, 1887, and Bulletin 45 of the United States Geological Survey.

†*Exogyra ariatina* clays of the Austin section.

the south bank of the river, the third and lower phase of this formation is seen in a short bluff composed of a rapidly corroding, chalky lime rock. This isolated outcrop is the only one of the formation in Arkansas, and with one exception,* the only one recorded east of Denison, Texas, and is identical stratigraphically, lithologically and faunally with the Comanche Peak horizon. This is the lower portion or Fredericksburg division (Comanche Peak group of Shumard) of the American cretaceous, which attains its great development in the Butte region of western Texas, where it is distinctly seen to rest upon the upper portion of the Trinity beds.†

These two divisions, the Washita and the Fredericksburg, with the next to be described, occupy most of the medial slope of the Little river basin south of the mountains in the Indian Territory beneath the gravel plateau and the outcrops of Rocky Comfort chalk, and all the slopes of Red river south of the Ouachita chain as far west as the 98th meridian, its western edge being denuded.

The eastern extent of the Washita and Fredericksburg beds in Arkansas is concealed by superficial deposits, but their lithologic and stratigraphic appearance are so entirely different from those of any of the overlying formations, that they can never be mistaken one for the other. Not only are the characters of the rock, but even the aspect of its topography and flora are different.

The contacts of the Comanche series, both above and below, are obscured in Arkansas, but have been seen by the writer, as described in the papers mentioned. In Arkansas the

*Wm. M. Gabb describes a fossil,—*Chemnitzia occidentalis*, which was found at Indian Territory (Choctaw Mission). It is accompanied by *Globioconcha elevata*, Shum., *Ammonites vespertinus*, Morton, *Gryphaea pitcheri*, *Turritella planilateralis*, Con., all of which are characteristic of this horizon. Journal Academy of Natural Science, Philadelphia, 20 Sec. Vol. xiv, p. 10.

†The fossils, which I had but a short time to collect, are the same as those always found in these beds. *Gryphaea pitcheri* (type var.), Morton, *Exogyra texana*, Roem., *Neithea occidentalis*, Con., *Cardium hillanum*, Sow., *Pholadomya sancta-sabæ*, Roemer, *Ammonites pedernalis*, V. Buch., *Heteraster texana*, Roemer, and others as yet undescribed.

beds of the Trinity formation certainly dip beneath them, and in Texas, following the upper Cross Timber from Red river southward to the Colorado, I have frequently seen the Comanche series rest upon them. The relations of this formation are shown in the cross section number. The Comanche do not extend north of the Ouachita mountain system, which may account for the fact that its true stratigraphic position has so long remained unknown.

Owing to the concealment by the quaternary there are no favorable exposures for securing the dip of these lower cretaceous rocks in Arkansas, but the general indications are that it is to the southeast.

General Remarks upon the Comanche Series Above the Trinity.—The Comanche series has not been studied systematically, as a whole, and its occurrence in Arkansas at a point 200 feet lower and 200 miles east of any previously recorded outcrop is of interest. It extends interruptedly across the state of Texas from Cerro Gordo, Arkansas, to Sonora, Mexico, and is characterized by the flat-topped hills (buttes) west of Austin and Fort Worth. Everywhere along its eastern line, however, it dips underneath the upper cretaceous. There is also reason to believe that its upper beds outcrop in the Salines of Louisiana* and in the Island of Jamaica.

In Texas the formation is highly disturbed in places, and its probable reappearance at these eastern points shows that there must have been great corrugation after the close of this period. It is also probable that there was an extensive lapse of time between its close marked by a land epoch and the beginning of the upper cretaceous subsidence, as is shown by the absolute cessation of its animal life. Not a single one of its numerous species is found in the later American cretaceous, although in Europe many of them do pass into the lower chalk beds there, which are the equivalents of the upper cretaceous, or *Exogyra costata* series, in this country. Another evidence

*Mr. Lawrence C. Johnson of the U. S. Geological Survey, who has studied these beds in Louisiana, kindly allowed me to examine its fossils, which, although poorly preserved, resembled many of the fossils of the Comanche series.

of the greater age of the Comanche series is the metamorphism its rocks have undergone. They are all of deep sea origin, and like certain beds of the upper cretaceous, were once pure chalk, and in a few places are still so,* but by gradual chemical solution and crystallization the chalks have been changed to firmer limestones.

The beds of the Comanche series, except those of the Cerro Gordo marly clays and the Trinity beds, have no areal exposures in Arkansas. These marls weather into sterile, yellow clay lands, which outcrop along the "line road" in the western part of Little river county. The surface outcrops, like those of the post-tertiary, are characterized by a forest growth of pine. The surface weathering of these lower cretaceous lime formations, as seen, however, along the upper portion of Little River valley where almost immediately upon crossing the Choctaw line extensive patches of the gravel plateau have been washed away. Here they appear as small prairies, of a thousand acres or more in extent, and so different are they in every character from the surface features of the immediately adjacent region in Arkansas, as well as from all the United States east of them, that the transition is very striking. It is a change in a single step from the superb forest covered topography of the great Atlantic timber belt of the eastern United States to the grass and flower covered prairies of the western Texas plains. Here, in the entirely different soil, the peculiar Texas grasses grow rank and high, and hundreds of plants occur which are seldom seen across the Arkansas line. These small prairies of the Comanche series differ greatly from the upper cretaceous prairies to the east. They do not represent the main body of the western Texas prairie, however, but merely the easternmost outliers, exposed by the removal of the quaternary, for the great gravel plateau and its accompanying forests, still continue to occupy the uplands far west into the Choctaw and Chickasaw country.

*In the strata of Travis, Burnet, Comanche and other counties of Texas there are great beds of pulverulent chalk, accompanied by flint nodules belonging to this formation. See analyses of chalk from Burnet county, Texas.

Perhaps one of the most interesting features of the Comanche series is the abruptness with which it terminates against the Ouachita mountain system in Indian Territory, not a single exposure of its beds being known north of that great barrier, except in southern Kansas (Soldier's creek) to which these strata probably extended through the Arbuckle-Wichita gap.* This northern contact with the southern limit of the mountains although usually concealed by the Red river loess, can be clearly seen at many places, especially about four or five miles north of Caddo on the Missouri, Kansas and Texas railway, and near Ardmore on the Santa Fe railway.

*Since this report was prepared for press, Prof. Francis W. Cragin in the Bulletin of Washburn College, Topeka, Kansas, for January, 1889, publishes a section of "an island like remnant of the cretaceous whose fauna is foreign to anything known north of the Arkansas river," occurring in portions of Barber, Comanche and Kiowa counties, Kansas, which undoubtedly represent the Comanche series, Fredricksburg division (No. 5, of Prof. Cragin's section) and probably the Trinity beds (No. 6). This shows undoubtedly the pre-cretaceous gap in the Ouachita system between the 99th and 100th meridians.

CHAPTER XII.

LOWER CRETACEOUS—CONTINUED.

*The Trinity Division.**

The great east and west valley of the Little Missouri and Messer's creek drainage, extending parallel with and south of the Ouachita mountain system, and the erosion of the gravel beach that once extended over it, have been described. The old Fort Towson road that threads the valley has also been mentioned. If we descend into this valley from the gravel plateau, as represented in the accompanying section (See Cross Section No. 2), at any point of its extent, say from Plaster bluff south of Murfreesboro, or from Centre Point, great changes in the character of the country are met with. The gravel, except such debris as remains from the destruction of the plateau, which has been eroded away, or which forms terraces of later base levels, is soon succeeded by its basal ferruginous sands, and these in turn are succeeded by a firm white or yellow sand often filled with small concretions of iron pyrites and perforated by craw-fish borings. This last mentioned sand is yellow at the surface, but in the ravines or wells, where fresh vertical exposures are seen, it is greenish white mixed with clay, so that in drying it often becomes almost as hard as burnt brick. This greenish white is often mottled by purplish blotches resembling the Potomac sands seen between Baltimore, Md., and Washington, D. C., while in its lower horizons it is intercalated sometimes with beds of deep red or terra cotta colored clay.

Continuing downward and across the valley these sands and mottled clays are found to be varied occasionally by horizontal strata of thin fossiliferous brecciate limestones, which,

*A preliminary notice of this formation was published in Science, Jan. 13, 1888.

upon exposure to the atmosphere, decompose and produce a rich lime or "black land" soil.* Still further northward, these limestones and sands are found resting upon the upturned "mountain rock" when not obscured by the plateau gravel, which nearly everywhere covers this parting. Occasionally beds of massive gypsum are found accompanying the limestones, while near its base are occasional trunks of trees buried in coarse sand and grit, and changed to lignite. In these basal lignitic beds are also found the remains of fishes and of huge saurians. These sands, clays, limestones and marls constitute one continuous formation, which is here collectively termed the Trinity.

This Trinity division is easily distinguishable from the other divisions of this series by its color, lithologic, stratigraphic and paleontologic characteristics. In general, it is a series of calcareous, gypsiferous, argillaceous sands, alternating with numerous thin strata of firm yellow crystalline bands of limestone, which vary from one inch to one foot in thickness.

The grayish yellow limestone strata are usually persistent in extent, firm, ringing under the hammer's blow, often crystalline, and differing from most of the overlying cretaceous beds in that they were originally composed almost entirely of small littoral shells, which can be seen in some places where the brecciate structure of the rock is as well preserved as that of the "coquina" or shell rock now in process of formation on the Florida coast. Generally, however, the shell structure has been dissolved and replaced by crystallized calcite. Upon exposure, the hard rocks generally exfoliate into thin fissile slabs, their surfaces often exhibiting ripple marks. The limestones and marls of the Trinity are never glauconitic or chalky as are those of the upper cretaceous series, nor have they the massive, flinty and decomposing character of the Comanche series, while the contained fossils are of entirely different species. The sands or sandy strata, although they constitute

*The lime beds are popularly known as the "black lands," a term which, owing to its application to formations of so many different ages has no distinctive geologic meaning whatever.

the bulk of this division, owing to loss of structure under atmospheric alteration and dense forest growth, are seldom noticeable, except in recently formed gulches.

The limestone beds of the Trinity formation are highly fossiliferous, and the shells which belong to but few genera and species, occur in the greatest profusion. Slabs of the limestone are sometimes perfect masses of minute shells, consisting mostly of *Anomia*, *Corbicula*, *Lucina*, *Ostrea*, and *Pleurocera*. The sands are, also, fossiliferous, but in them only the casts are preserved, which, owing to the excess of pyrites almost immediately lose their identity upon exposure.

Although the area of this formation is seldom more than two miles in width it has great length, as may be seen upon the map, appearing only in the great east and west valley, from which the gravel plateau has been denuded. The most eastern locality is the outcrop in the bed of Wolf creek, two miles west of Antoine in Pike county, where its lignites and the coarse blue sands are found. The first exposures of any extent are further west in the valley of the same creek, north of Wolf Creek Post-office, where the continuation of the formation in all directions is obscured by the gravel plateau point that forms the divide between Wolf creek and the Antoine. From this locality outcrops are almost continuous westward to Ultima Thule, except in a few places where the high gravel water-sheds, and wide alluvial flood plains obscure it, while from Ultima Thule it continues to and beyond Eagletown in the Indian Territory. The builders of the old Fort Towson military road, followed the strike of this formation; presumably to avoid the heavier growth of timber, and to avail themselves of the small prairies that originally marked its course.

Deviating northward from the main road at Wolf Creek Post-office and ascending Wolf creek for two miles, some good exposures of the Trinity are seen. About one quarter of a mile from the village, yellow marls appear beneath the gravel, accompanied by alternations of thin slabs of limestone containing *Anomia*, *Serpula*, *Ostrea*, etc. In section 10,

8 S. 24 W. the formation outcrops in the ravines and on the hills where the gravel has been denuded.

In Mr. Parson's field, in the southwest quarter of section 11, 8 south, 24 west, is a superb display of these Trinity sediments, and millions of specimens of the shells of *Ostrea franklini* and *Pleurocera strombiformis* are strewn over the soil. Similar exposures are seen also in several fields in this neighborhood. The coarse basal sands with lignite occur low in the banks of Wolf creek. From Vaughan's creek, east of Brocktown Post-office, to the west bank of the Little Missouri and Rolling fork, is the most extensive outcrop of the Trinity, occupying most of the low uplands and forming the sandy second bottoms of the Little Missouri. The thin limestones of the formation are conspicuous along the low secondary ridge upon which runs the Towson road, and the yellow crawfish sands constitute much of the county.

The gypsum bluff ("Plaster bluff") of the Little Missouri, section 30, 8 south, 25 west, affords a very fine vertical section of the Trinity formation. The summit of the entire county south of the river is the great level plateau, the highest of which is about 150 feet above low water on the river. The river is constantly undermining this south bank, and the following section is exposed:*

Section No. 8, Gypsum Bluff of the Little Missouri, two miles South of Murfreesboro, Pike County:

- | | | |
|----|---|----------|
| 9. | Quaternary gravel forming the level of the country above the bluff..... | 50 feet. |
| 8. | Finely comminuted, blue, arenaceous gypsiferous sands and clay marl, weathering as above with fossils <i>Ostrea</i> , <i>Anomia</i> , <i>Pleurocera</i> , etc | 15 feet. |
| 7. | Pure, massive saccharoidal gypsum in several bands | 10 feet. |
| 6. | Arenaceous, calcareous stratum of harder rock... | 1 foot. |
| 5. | Green clays and sands as in No. 8, with numer- | |

*Dr. Owen gives a section at this place in his Second Report, p. 124. Our details do not agree.

- | | | |
|----|--|----------|
| | ous shells of <i>Anomia</i> and other forms..... | 3 feet. |
| 4. | Fossiliferous bands of fissile, arenaceous lime-
stone | 1 foot. |
| 3. | Blue marl and shales..... | 5 feet. |
| 2. | Fine white and blue sandy marl, oxidizing to terra
cotta red | 4 feet. |
| 1. | Fine grained sands and marl with irregular de-
posits of lignite and bones of saurians..... | 40 feet. |

Huge slabs of limestone from under which the marls have been eroded stand upon edge on the slope.

Above the top of this section Trinity beds doubtless extend for 100 or 200 feet higher, while below they extend far beneath the low water mark of the river, showing that this division must be more than 300 or 400 feet in aggregate thickness.

The base of this "Plaster bluff" does not represent the base of the formation, however, for upon ascending the Little Missouri and the Rolling fork to a point about four miles a little west of north of the bluff, many lower strata are passed, all of which dip beneath the beds exposed at "Plaster bluff." On the south bank of the Rolling fork at its mouth, is a massive stratum of limestone, composed almost entirely of oyster shell breccia, and one mile north of this, still lower limestones of the Trinity can be seen resting directly upon the tilted paleozoic rock. Rocks of this division are well displayed through the northern part of township 8 S., 27 W., and the southern part of township 7 S., 27 W. Nearly all of township 8, range 28, excepting the southeast quarter, is composed of this formation, the beds having been exposed by the drainage of Messer's creek. The drainage of the Saline, Cossatot and Rolling fork of Little river have all exposed Trinity beds. The gravel plateau between the Cossatot and Saline, however, has not been removed, so that the east and west continuity of the Trinity division is broken by this watershed. The Trinity sands extend southward down these rivers a mile or two. The town of Chapel Hill, in Sevier county, is situated upon its southern border. The Trinity beds underlie the old town of Ultima Thule on the Arkansas-Choctaw line, while half a mile

north they rest upon the paleozoic. They extend also several miles south down the valley of the Rolling fork, though they are obscured by the overlying drift, and they underlie the Comanche series at the crossing of the line road and Little river, as seen near the old salt well* on the south side of the stream.

Although the occurrence of beds of this division have not yet been traced through the Indian Territory beyond Eagletown, there is no doubt of their direct stratigraphic continuity through that country into Texas.

The Trinity Division in Texas.—The upper Cross Timbers of Texas occupy a great eroded depression which marks the paleo-mesozoic contact exactly as the Trinity follows it in Arkansas. Beginning at Red river at the town of St. Joe, a great westward facing scarp can be traced continuously by the way of Decatur, Stringtown, Millsap, Thorp Springs, Dublin, Comanche, and westward to the Granbury and Weatherford public road, twelve miles from Weatherford. This road follows the scarp of the valley, which is identical here with that of the Brazos valley.

In the Brazos valley, I found beneath the base of the Comanche series, whose contact is here well marked, *Ostrea franklini* in a layer of recent looking yellow clay shale and an earthy limestone. There were found here also the accompanying *Anomia*, and *Pleurocera strombiformis* and a *Nerita* not as yet found in the Arkansas beds.

In descending the Brazos valley, along the Texas Pacific railway track, from Weatherford (which is situated on the basal layers of the Comanche series), the Millsap pure white sands, similar in lithologic consistency to the greensands of Arkansas, and thin beds of limestone similar to those found at Wolf creek, are well displayed in stair-like descending order, the hard layers forming the table lands, the argillaceous sands forming the precipitate scarps. Four miles east of Millsap station, the contact with the Comanche series is beautifully

*These are the wells mentioned by Owen in his second report, p. 112. His section and description are misleading, however.

shown, and here were found huge vertebrate remains, which Professor E. D. Cope informs me are those of Dinosaurs. The thin arenaceous limestone bands are identical with those seen along the Fort Towson road from Antoine to Ultima Thule, and invariably contain the remains of *Ostrea franklini* and *Pleurocera*. These beds do not have the red color, however, that characterizes those of Arkansas, and for reasons expressed elsewhere they are regarded as above the Arkansas formation.

The Trinity beds of the Brazos valley continue northward in Texas to Red river, and are beautifully shown on the Weatherford-Decatur road, eighteen miles southwest of the Weatherford, and one mile west of Stringtown Post-office. At this last point is a small butte standing fifty feet above the surrounding prairie, the capstone of which is a thin band of arenaceous limestone. In the marls forming the body and scarp faces of this butte, are well preserved fossils, such as the large forms of the *Ostrea franklini*, *Pleurocera*, *Trigonia*, and *Anomia*.

This eroded escarpment and its outcrops, extend in Texas from west of Granbury, to the state line north of St. Joe, and follows approximately the eastern border of the so-called upper Cross Timbers. It is also visible at the town of Comanche, and probably reaches across the carboniferous area to the plains. Six miles south of Sweetwater a few feet of its beds probably constitute the base of the neocomian buttes, which rest unconformably upon the gypsum beds there. At Tucumcarri mountain, New Mexico, these sands are probably represented by somewhat similar lithologic features, but contain no fossil remains. South of the Brazos these beds are finally seen to the Colorado, the base of Post mountain, in the town of Burnet, being composed of them.

The Trinity rocks are clearly of near shore and shallow water origin. The thin fissile lamination, the arenaceous character of the limestones, often gradating into sandstones; the contained fossils of brackish water character; the lignitized trunks of trees, the ripple marks, and the absence of deep

sea sediments such as chalks, greensands, etc., all attest this fact.

The Stratigraphic Position of the Trinity Division.—In Arkansas the Trinity rests unconformably upon highly disturbed paleozoic rock. In Texas it rests upon the permian at St. Joe, and upon the carboniferous at Millsap, upon the red beds ("Keuper" of Marcou) at Sweetwater, and upon the Silurian at Burnet. It is the lowest exposed mesozoic terrane in Arkansas. Owing to its structure and rapid decomposition on exposure, it is impossible to ascertain the exact dip of the beds. Most of the exposures, however, indicate a southern direction in Arkansas and an eastern one in Texas. In general, its dip seems at right angles to the strike of the mountains which no doubt formed the northern limit of their deposition.

Thickness of the Trinity.—The thickness of the exposures of the Trinity cannot aggregate more than 400 feet. By actual measurement across the valley north of Centre Point it is 250 feet. How much of it has been denuded by the great quaternary inundations cannot be estimated.

The Color of the Trinity Beds.—The deep red or terra cotta color which is especially noticeable towards the base of this formation, both in Arkansas and Texas, is a subject of much inquiry. It is made especially interesting in that these red colors mark a great series of permian, jurassic, and perhaps triassic beds in Texas. When we consider that the now degraded Ouachita mountain system extending from Rockport, Arkansas, to the 100th meridian, the following explanation of similar colors in similar formations in England, by Sir Charles Lyell,* seems plausible :

Origin of Red Sandstone and Rock-salt.—"In various parts of the world, red and mottled clays and sandstones of several distinct geological epochs, are found associated with salt, gypsum and magnesian limestone, or with one or all of these substances. There is, therefore, in all likelihood, a general cause for such a coincidence. * * * * *

*The Student's Elements of Geology, by Sir Charles Lyell, p. 374, Harpers, New York, 1886.

"These red deposits may be accounted for by the decomposition of gneiss and mica schist, which in the eastern Grampians of Scotland has produced a detritus of precisely the same color as the Old Red Sandstone. * * * *

"It is a general fact, and one not yet accounted for, that scarcely any fossil remains are ever preserved in stratified rocks in which this oxide of iron abounds; and when we find fossils in the New or Old Red Sandstone in England, it is in the grey, and usually calcareous beds, that they occur."

The igneous rocks from which these Arkansas-Texas beds were derived, if this hypothesis be tenable, were no doubt those of the much degraded Ouachita mountain system.

In parts of Texas there are in places thousands of feet of intervening mesozoic strata. The parting in Arkansas and Indian Territory is usually obscured by the gravel plateau, or its debris, but the actual contacts have been seen by both Professor Hay and myself in numerous places. Its contacts with the overlying beds in Arkansas, however, are nowhere visible. The inundation which deposited the plateau gravel which covers its southern and upper border throughout this state, except perhaps at Little river, where the Comanche series probably rests upon it, no doubt washed away much of its upper beds. In Texas, however, innumerable contacts between this formation and the base of the Comanche series have been seen by the writer, and prove that it is below and older than our oldest cretaceous.* The most eastern exposures known in Pike county, Arkansas, are probably covered by the upper cretaceous series, although the direct contact is obscured

*In the American Journal of Science for April, 1887, the writer intimated that the stratigraphic position of the upper members of these beds in Texas might prove them to be jurassic, and gave them the name of "Dinosaur sands." In the same journal for October, 1887, pp. 305-306, he again expressed the following opinion, which his observations in Arkansas have strengthened: "The basal, or Dinosaur sands of my section, which are interpolated (Am. Jour. Sci., Third Series, Vol. xxxiv, No. 202, Oct., 1887) between the Fredericksburg division and the undoubted carboniferous, are the shore detritus of the mesozoic sea when it bordered upon the carboniferous continent. The lowest marine fauna of this division is seen in Parker county, Texas, and careful study of the same may prove jurassic affinities."

by the post-tertiary gravel, but the marls of the latter are found within a mile of the former. In Texas and Indian Territory the westernmost beds are beneath the neocomian.

Reviewing the stratigraphic evidence afforded by Trinity formation, it seems to be clearly older than any cretaceous rocks hitherto described in this country, a fact which is verified by the paleontology as shown in the next chapter.

The stratigraphic position beneath the lowest Comanche series, which is of very early cretaceous (neocomian), and the extreme difference in the character of the sediments and fossils, confirm the opinion that the rocks are either uppermost jurassic, lowest cretaceous (Wealden) or transitional jura-cretacic. They are at least older than the oldest American cretaceous rocks hitherto known, and mark the littoral stages which characterized the beginning of the first grand subsidence of cretaceous times.

Relations to Other Areas.—It is premature to attempt definite correlations of the Trinity beds with the rocks of the far west, but the writer has made sufficient observations to prove beyond all doubt that they are newer than the gypsum bearing beds of Texas, and that there is a stratigraphic non-conformity between them, as seen at Sweetwater mountain, Nolan county, Texas, and at Tucumcarri mountain (Little Tucumcarri of Marcou) New Mexico, where the probable continuation of the Trinity sands is seen intercalated between the jurassic and the neotomian. In general lithologic appearance, and in occurrence of saurian remains, these beds bear striking resemblance to the *Atlantosaurus* beds of Canyon City, Colorado, and Como, Wyoming, but no analogous molluscan fauna has as yet been found in them, excepting the distant resemblance of two species, the *Neritina nebrascensis*, M. & H., and *Liaplacoides veterius*, M. & H., with species of the same genera in Arkansas.

The relations of these beds to the trans-Mississippi formation is at present only conjectural, but the Potomac formation of the North Atlantic region, and the Tuscaloosa formation of the Mississippi-Alabama region occupy an analogous strati-

graphic position, and are most probably the eastward continuation beyond the Mississippi, of these transitional jura-cretacic beds.

There is great identity in color and lithologic appearance between certain of the Trinity beds and those of the Potomac formation, and in the organic remains of the plastic clays of New Jersey, which have been included in the Potomac beds by McGee, which contain the *Amboniocardia cookei*. A careful comparison of the plant and vertebrate remains, which are especially abundant in both the Trinity and Potomac formations, may prove even a closer analogy between the two.

The Trinity formation has certain broad lithologic resemblances to the great gypsum deposits of the Texas Pan-handle region, but close comparison shows striking differences and the writer has demonstrated that the former are entirely above them, as may be seen at Sweetwater and elsewhere.

CHAPTER VIII

graphic position, and are most probably the eastward continuation beyond the Mississippi, of these transitional jura-cretacic beds.

There is great identity in color and lithologic appearance

CHAPTER XIII.

PALEONTOLOGY OF THE TRINITY DIVISION.

In conformity with their littoral character the Trinity beds are accompanied by a mixture of vegetal, vertebrate and brackish water molluscan remains. The trunks of the lignitized trees found commingled with vertebrate remains are indicative of the proximity of land. In the molluscan shells we have a fauna in keeping with this fact.

The molluscan fauna of the Trinity beds of Pike, Howard and Sevier counties is of much interest to the geologist, in that it throws new light upon the age and relations of our North American cretaceous. It has been shown in the previous chapter that the stratigraphic position of the Trinity beds in Arkansas, and their upward continuation in Texas, the Dinosaur sands,* is beneath the oldest hitherto known marine cretaceous of the United States. The molluscan fauna is confirmatory of this position.

The Trinity fauna as a whole is marked by the few species which it contains, and with some exceptions by the immense number of individuals of these species, by its non-occurrence in any other geologic horizon exposed in America, and by its remarkable resemblance to certain European faunas of similar stratigraphic position. Associated with this fauna in its arenaceous beds are numerous plant and animal remains to be mentioned.

The shells are all of forms whose living representatives are known to inhabit brackish waters, a character which is further verified by the stratigraphy, and the accompanying vegetal and animal remains. The species, furthermore, are remarkably similar and in some cases identical with forms hitherto known to occur only in certain local beds of the basal cretaceous and

*See American Journal of Science, April, 1887, Geology and Topography of the Cross Timbers of Texas.

the upper jurassic of western Europe, known as the Wealden and Purbeck respectively. The presence of so many deep marine European forms in the American cretaceous can be readily explained upon the ground that they lived in the deeper waters of the same great ocean, but the occurrence of these brackish water, littoral forms so far apart cannot be explained altogether on this hypothesis.

Among the forms so far identified are the following, some of which are provisionally referred to as new species, but most of them bear remarkable resemblance to forms from the upper Purbeck and basal neocomian or Wealden beds of Europe:

Ammonites walcotti, *sp. nov.*

Plate I, figs. 1, 1a, 1b.

Discoidal, flattened; with bi-flexuous, almost indistinct, markings at wide intervals; a slight longitudinal depression in the center; keel narrow but well rounded; whorls, three or more; interior margins sharply angular; outer whorl five times the diameter of all the others, center whorl deeply depressed. Sutures separate, deeply marked and well defined; lobes and saddles not defined clearly in specimen, but the saddles are angular and well defined; lateral and dorsal lobes much larger than interior and inner laterals. Greatest diameter, 9 cm.; thickness, 2.2 cm.

Only one specimen of the ammonite was found, and this was deeply imbedded in a shell breccia composed of the other species figured herewith. The more perfect side (fig. 1) was imbedded, while the other was water-worn, as shown in fig. 1a.

Careful examination of the literature and specimens of the Boston and Washington libraries and museums failed to reveal any figured species with which this one can be identified. It resembles generically the group *Harpoceratidae* (genus *Ludwigia*, Boyle), which is peculiar to the upper jurassic of Europe, and also *Ammonites yo*, D'Orb, of the lower neocomian. The absence of this ammonite from the great mass of the Trinity strata, except in the place indicated, suggests that it may be an older fossil reimbedded in the Trinity, but its preservation and delicacy of structure would seem to render this impossible.

Locality, mouth of Caney creek, branch of Prairie creek, near Murfreesboro, Pike county, Arkansas.

Named in honor of Mr. Charles D. Walcott, of the United States Geological Survey.

Neritina nebrascensis? M. & H.

A small *Neritina*, indistinguishable from the above species, is found in the Trinity beds.

Pleurocera strombiformis, Schloth.

Plate II, figs. 1, 2, 3, 4, 5, 6, 7, 7a, 7b, 8, 9, 10, 11, 12, 12a.

Plate III, figs. 6, 6a, 6b, 6c. Copies of European figures.

The characters of this shell are well shown in the numerous figures of the Arkansas specimens (1-11 inclusive, on Plate II). It is by far the most common and characteristic shell of the Arkansas and Texas Trinity beds, occurring in great numbers almost everywhere. Figs. 12 and 12a are from the upper Cross Timber (Dinosaur) sands of Wise county, Texas. There is great variation in size, apical angle, and marking of individuals, but in general they agree in every point of identity with the characteristic European brackish water Wealden fossil, *Melania* (*Pleurocera*) *strombiformis*, Schloth, and especially as figured and described from Halberstadt, Germany, by Dr. Wilhelm Dunker,* copies of whose figures are given on Plate III for comparison. This species has never been found hitherto elsewhere than in the brackish Wealden and Purbeck beds of Germany and England, and its occurrence in these beds of Arkansas and Texas is a remarkable confirmation of their approximately synchronous age. Concerning the European form with which this American species is identical, Dr. Wm. Dunker says:†

"The *Melania* (*Pleurocera*) *strombiformis* is a very characteristic fossil of the Wealden formation occurring in beds peculiar to that formation and of broad distribution, occurring

*Monographie der Norddeutschen Wealdenbildung, Ein Beitrag zu Geognose und Naturgeschichte der Vorwelt, von Dr. Wilhelm Dunker, etc., Braunschweig, 1846, pp. 50-51, Plate 10.

†Op. cit., p. 51.

not only in North Germany and other portions of the empire, but in southern England, where it is less frequently met, however."

The specimens figured are from the higher beds of the Gypsum bluff of the Little Missouri river, Pike county, Arkansas.

Vivipara cossatotensis, *sp. nov.*

Plate III, figs. 4, 4a and 5, 5a.

The two specimens figured are from a well in the yellow Trinity sands near Chapel Hill, Sevier county, Arkansas. They are poorly preserved casts, but show clearly their generic characters. They possess all the generic features of *Vivipara*, and are larger than the only jurassic species of that genus hitherto found in America, the *Liaplacodes valvata*, Meek and Hayden,* from the alleged jurassic of the Black Hills of Dakota.

Length of largest shell, 4.2 cm.; diameter, 2 cm.

Buccinopsis ? conradi, *sp. nov.*

Plate III, figs. 2, 2a.

This large cast occurs in the gypsiferous marls of the upper part of the gypsum bluffs of the Little Missouri river, associated with *Arca gratiota*.† Its mineral composition, sulphates of lime and iron, cause it to decompose rapidly on exposure. It is almost identical in general contour with the figure of *Buccinopsis parryi*, Conrad,‡ which comes from strata of the Pecos plateau of Texas and northern Mexico, theretofore supposed to be cretaceous, but which the present writer believes, from its peculiar fauna (not found in the Comanche series) and its lower stratigraphic position, to be upper jurassic, of which the white *Nerinea schotti*, Conrad, limestone is especially characteristic. The new specific name *conradi* is here applied to the Arkansas species, owing to certain slight differences in contour and surface markings, which will be quite apparent upon comparing the two figures. As remarked by Mr. Conrad (op.

*See Paleontology of the Upper Missouri, Meek and Hayden, p. 116.

†Plate IV, figs. 2, 2a.

‡United States and Mexican Boundary Survey, Vol. I, Part II, p. 158; Plate XIII, figs. 4, 4a, 4b.

cit.), "this cast cannot be referred to any (previously) known genus." It is probable that the peculiar shape of this shell, which prevents its generic determination, may be due to distortion from pressure.

Ostrea franklini, Coquand.

Plate V., fig. 1-18a.

Plate VI., fig. 19-25.

Plate VII., fig. 28-30.

- O. *cretacea*, Owen (not Morton), in part, Second Report of the Geological Survey of Arkansas, Plate VII, figs. 3a, 3b, and 7, and Plate VIII, fig. 8.
- O. *franklini*, Coquand, Monographie du Genre Ostrea, Plate XXIII, figs. 8-10.
- O. *multiformis*, Koch and Dunker, 1837.
- O. *virgula*, de France, de Lorial, Description des Etages Jurassique Superieurs de la Haute Marne, Paris, 1872. Plates XIII, figs. 8-14.
- O. *dubiensis*, Cantejean, 1859, Kimmeriden de Montbeliard, p. 34, Plate XXI, figs. 4-11.

One specimen of this form was originally figured by Owen in his Second Report of the Geology of Arkansas, together with a form from the *Exogyra costata* series, under the name of *Ostrea cretacea* of Morton, a tertiary species to which it has only a vague resemblance. Coquand, a foreign paleontologist, in his great "Monographie du Genre Ostrea," recognized the separate position of this form and gave it the name of *Ostrea franklini*.

This oyster shows great variation between the attached juvenile stage (figs. 1-9, of Plate V), and the adult (figs. 29-29a of Plate VII.) The younger forms (figs. 1-9, Plate V) are all so exogyrate, and asymmetrical, as to belong properly to the artificial sub-genus *Exogyra*, and are usually more or less attacked by the flat lower valve, while the upper valve is deeply crenulate. As the animal became older the exogyrate beak gradually straightened and attenuated (as seen in Plates V and VI, figs. 10-19 and in figs. 12, 18, 27 and 28, Plates VI and VII), while the surface crenulations gradually became less

and less distinct, only being seen as slight radiæ (Plates V and VI, figs. 11, 16, 25, 26a.) In the adult stage (Plate VII, figs. 29, 29a) the corrugations have eliminated the radial lines, and the beak is no longer conspicuous. The asymmetry of the upper and lower valves continues, however, so that it can be said that throughout its life history the most conspicuous feature is this difference, the upper valve being always semi-globose (Plates V, VI, VII, figs. 1a, 15a, 19a, 29a), while the lower is always flattened.

Contrary to custom, figures of every possible type of variation of this shell are here published, nearly all of which were collected from the same spot, and all from the same horizon in the vicinity of Murfreesboro, Pike county, Arkansas. At the junction of the Little Missouri river and the Muddy fork, there is a massive stratum of limestone breccia, five feet in thickness, composed entirely of these shells. This species, which is the only oyster found in the Trinity beds, occurs throughout its extent both in Arkansas and in Texas. Upon comparison with European forms which have been described from various localities of the upper jurassic, such a remarkable similarity is apparent as to suggest the inquiry whether they, too, are not variations of the same form. The figures by De Leriol (op. cit.) of *Ostrea virgula*, de France, from the Portlandian and Kimmeridgean of France are almost identical with the exogyrate (Plate V, figs. 1-9), and acuminate varieties (Plates V, VI and VII, figs. 12, 14, 18, 26, 27, etc.), of *Ostrea franklini*. The radial lines and muscular impression are also very much alike. Fig. 3, of Plate V, a falciform variety, also resembles strongly many figures of the European *Ostrea virgula*, de France. The *Ostrea multiformis*, Koch and Dunker, and the *O. dubiensis*, Cantejean, from the Kimmeridge, greatly resemble the radiate and pointed varieties of *O. franklini* respectively.

The resemblance of this species to most European forms, all of which come from the similarly situated uppermost jurassic beds, is striking, and, taken in connection with

the stratigraphic and accompanying faunal evidence herewith presented, is indicative of the age of the Trinity beds.

Modiola, sp. ind.

Plate II, figs. 18, 18a, 19, 19a.

Only two specimens of this genus were found in Arkansas and one or two in Hood county, Texas. It has no obvious characteristics sufficiently distinct for specific differentiation, but it resembles the *Modiola lithodomus*, Koch and Dunker, and other species described from the local cretaceous and upper jurassic of Europe.

Arca gratiota sp. nov.

Plate IV, figs. 2, 2a.

Sub-quadrangular, globose, corrugate; beaks prominent and well defined; interior suture deeply defined. Length 7 cm. height 5 cm. thickness 5 cm. This large *Arca* occurs as a poorly preserved cast with *Buccinopsis*, and other shells of the Trinity formation in the higher layers of the upper end of Gypsum bluff. Named in honor of Col. J. R. Gratiot of Washington, Arkansas.

Arca (Barbatia) parva missouriensis, sp. nov.

Plate IV, fig. 5, also probably 4a, 4b.

Plate II, fig. 22.

This small and imperfect *Arca* is constantly found in the limestone slabs of the Trinity beds, but no perfect specimens showing distinctly the hinge area, have been found. Its surface features are well shown in Plate IV, fig. 5, which is the typical form. The interior of two imperfect valves, supposed to be the same as this species, are shown in figs. 4a, 4b. A cast of the interior is shown in Plate II, fig. 22.

Cyrena (Corbicula?) arkansaensis, sp. nov.

Plate II, fig. 20.

Plate IV, fig. 3, 3a, and 6.

Many individuals have been found of a shell which, so far as can be ascertained from external facies, is a *Cyrena (corbicula)*, for which the specific name of *arkansaensis* is proposed. Its size never exceeds 2 cm. in greatest diameter. Its surface features consist solely of the concentric markings characteris-

tic of most species of the genus. The shell occurs associated with the other forms described throughout the Trinity formation.

Corbicula ? (Astarte ?) pikensis, sp. nov. ?

Plate II, figs. 13, 13a, 14, 15, 16, 17.

Sub-triangular, flattened, strong longitudinal corrugations; persistently lunulate; apex inclined and usually well forward. The only right valve seen has one cardinal tooth and indications of lateral teeth. The only left valve seen has two cardinals and well defined but waterworn posterior and anterior laterals. Pallial line not seen. Average length 15 cm.; average thickness 1 cm. While the external contour and markings of this shell approximate the *Astartidæ*, its dentition and variation are those of the *Cyrenidæ*. The shell resembles in nearly every respect the *Cyrena astarteformis*, Koch and Dunker, from the Wealden of Halberstadt, Germany. I doubt its being specifically distinct from it.

The shells of this species occur by the millions throughout the Trinity beds in Arkansas, and especially in the limestone horizons, as seen along the Murfreesboro-Antoine road. They occur as calcite pseudomorphs in the massive shell breccia, or independently. It is not unsafe to say that nearly 90 per cent. of the lime-rocks of the Trinity formation is composed of this and three other species, to wit: *Ostrea franklini*, *Anomia, sp. ind.*, and *Pleurocera strombiformis*, Schloth. The specific name is from that of Pike county in Arkansas in which these fossils are found in greatest abundance.

Cardium ? sevieriensis sp. nov.

Plate II, figs. 21, 21a.

Poorly preserved fragments of individuals of this species occur in the limestone breccia of the Trinity beds, but the specimen figured, which gives little structural detail, is the most perfect one found. The shell is sub-globose, and marked with coarse, crowded radiating ribs; the anterior region is slightly flattened and the margins crenulated. Length, 2 cm., diameter, 4-5 cm., height, 2 cm.

Locality, near Murfreesboro, Arkansas. The name is for Sevier county Arkansas.

Anomia, sp. ind.

One of the most numerous species in the Trinity beds is a small concentrically striated *Anomia*, which can be readily distinguished from the large *Anomia argenta* of the upper beds by its universally smaller size, more regular contour and accompanying fossils. As the classification of the *Anomias* is unsatisfactory and imperfect, the writer will not at present attempt any specific diagnosis of the form found in the Trinity beds.

Serpula, sp. ind.

An unstudied serpula is found attached to the *Ostrea franklini* and other species of the Trinity.

In addition to the above, many species have lately been found which will be published in the scientific journals later.

Most of the above genera have wide stratigraphic range, but the species, except the *Ostrea franklini*, Coq., have never been identified before in this country, although the forms are apparently identical with certain well known European species. The *Corbicula*, *Pleurocera*, *Modiola*, and *Nucula* especially resemble those found in Wealden and Purbeck strata of England and Germany, and especially those described by Dr. Wm. Dunker* from the Wealden and uppermost jurassic strata of Halberstadt, Germany. The most striking of these shells is the turriculate, nodulose, univalve, *Pleurocera strombiformis*, Schloth.

The *Corbicula*, *Modiola* and *Ostrea* all present great affinity to the European, Wealden and jurassic forms. There is also a large bivalve, found in the Texas beds, but not in Arkansas, which has great resemblance to the genus *Amboniacardia*†

*Monographie der Norddeutschen Wealdenbildung.

†“In looking over the forms of Lamellibranchiate shells from the jurassic formations, in the vain effort to find some genus under which I could class this new form, I have been thoroughly impressed with the feeling that it was more intimately allied to the jurassic forms than to any of those from the European cretaceous. And I have a feeling resting upon this evidence alone, that the beds in which they occur

of the basal clays of New Jersey and a small *Modiola*, and *Nerita* which resembles the European Wealden.

represent that period on our eastern border, but the evidence is not sufficient to give basis for a positive opinion." Robert P. Whitfield, Monographs of the United States Geological Survey, 1885, Vol. ix, p. 23.

Lamellibranchiate shells from the plastic clays.

PLATE I

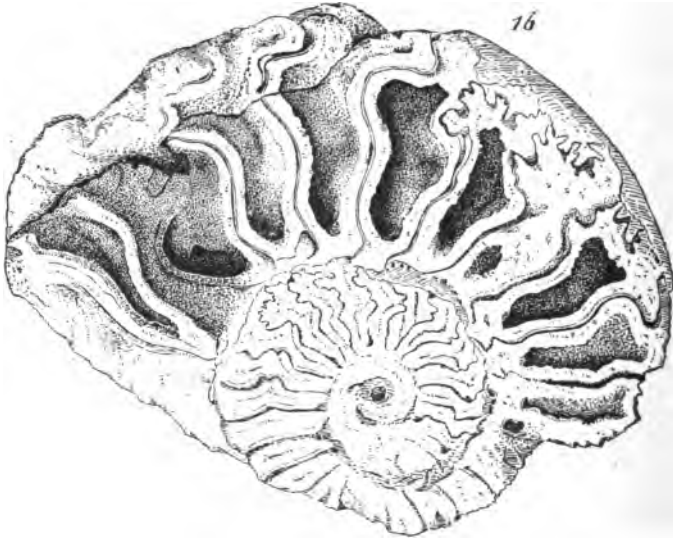
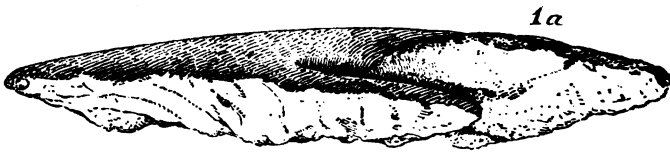
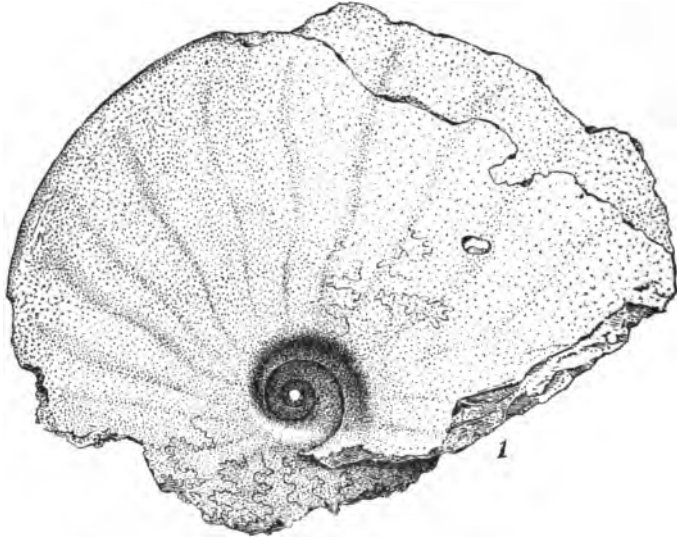
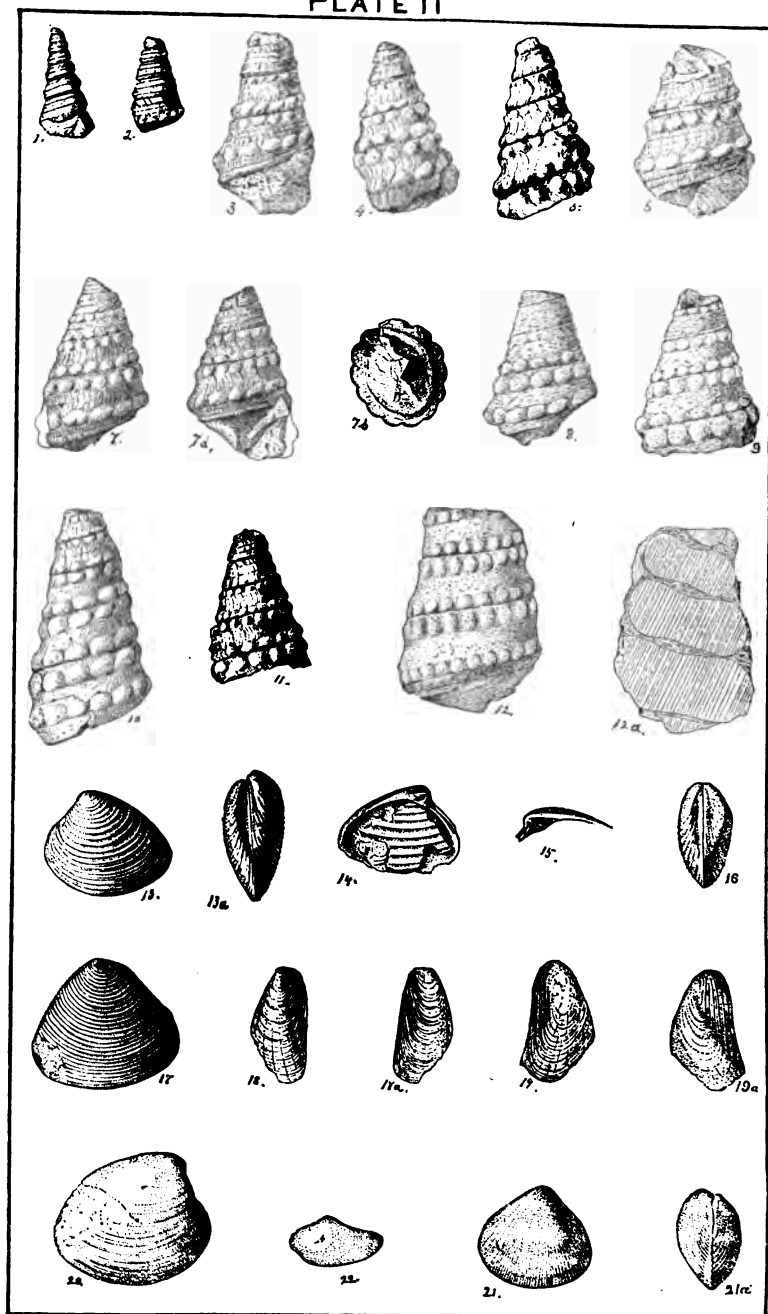


Plate I, figs. 1, 1a, 1b, *Ammonites walcotti*, *sp. nov.*, p. 128-

PLATE II



- Plate II, figs. 1-12a, *Pleurocera strombiformis*, Schloth, p. 129.
13-17, *Corbicula?* (*Astarte?*) *pikensis*, *sp. nov.*, p. 134.
18, 18a, 19, 19a, *Modiola*, *sp. ind.*, p. 133.
20, *Cyrena* (*Corbicula?*) *arkansaensis*, *sp. nov.* See
plate IV, and pp. 133 and 144.
21, 21a, *Cardium?* *sevieriensis*, *sp. nov.*, p. 134.
22, *Arca* (*Barbatia*) *parva missouriensis*. See plate
pp. 133 and 144.

PLATE III

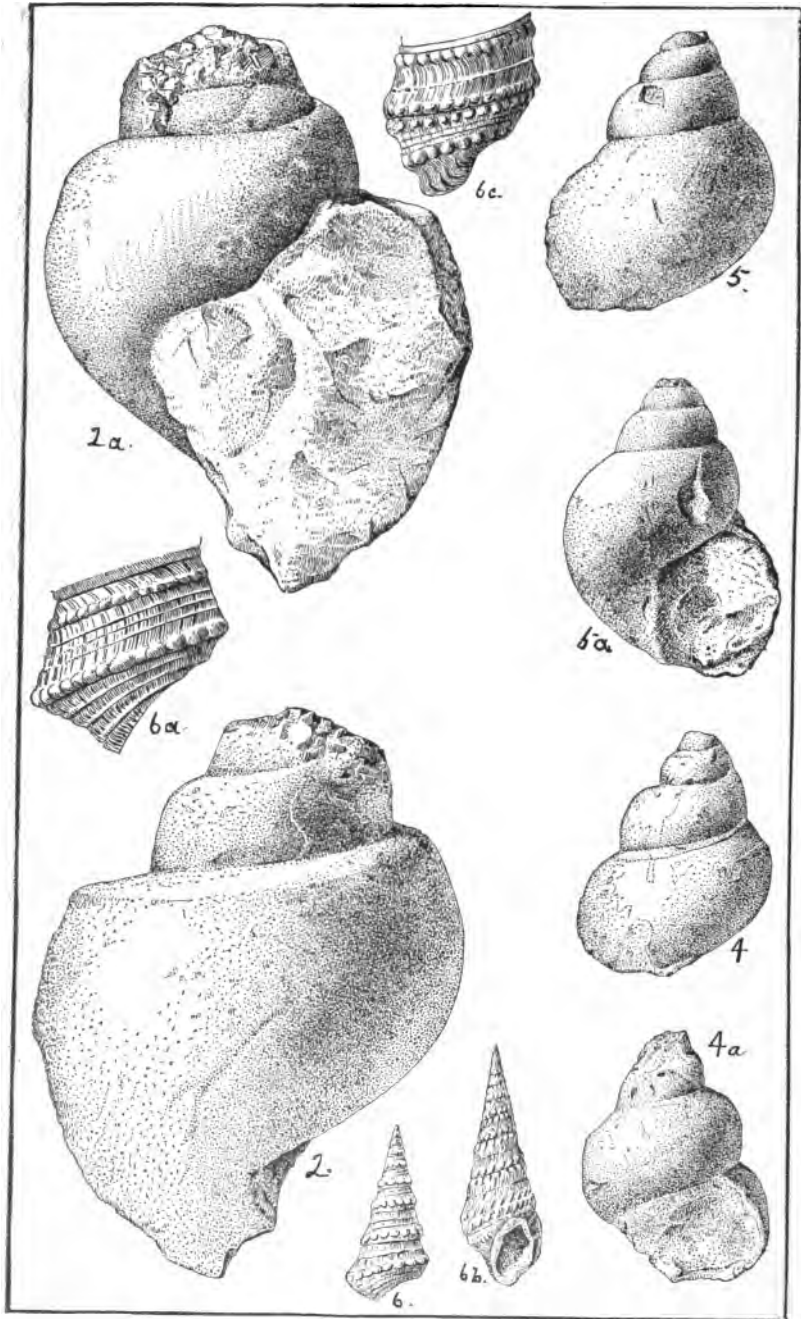


Plate III, figs. 2, 2a, *Buccinopsis ? conradi*, sp. nov., p. 130.
4, 4a, 5, 5a, *Vivipara cossatotensis*, sp. nov., p. 130.
6, 6a, 6b, 6c. *Pleurocera strombiformis*, Schloth.
Copies of Dunker's figures, p. 129.

PLATE IV

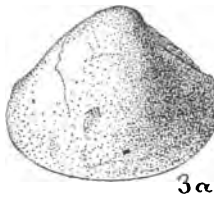
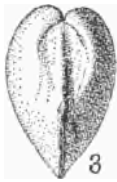
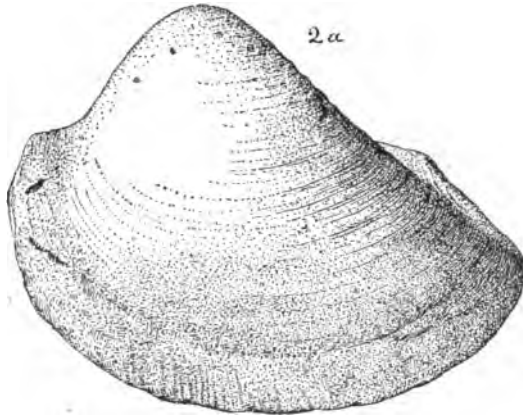
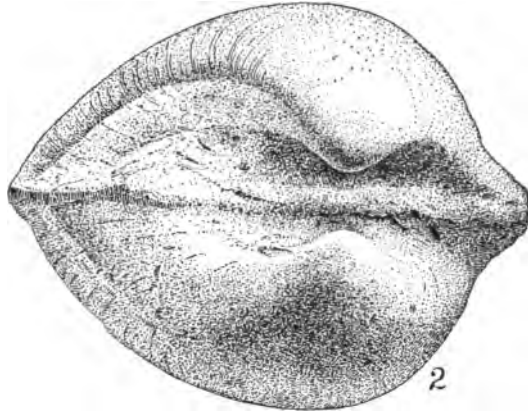


Plate IV, figs. 2, 2a, *Arca gratiota*, *sp. nov.*, p. 133.

3, 3a, 6, *Cyrena* (*Corbicula*?) *arkansaensis*, *sp. nov.*, p. 133.

4, 4a, 5, *Arca* (*Barbatia*) *parva missouriensis*, *sp. nov.*, p. 133.

PLATE V

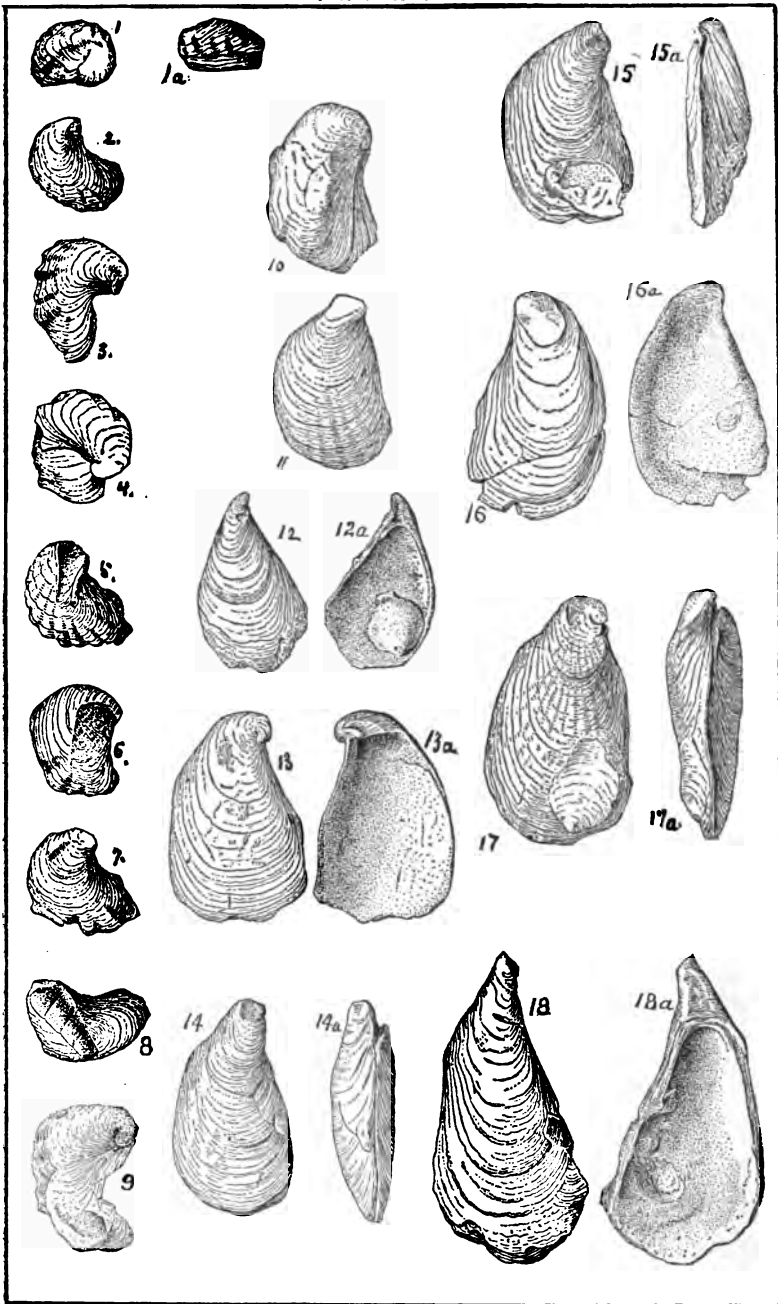


Plate V, figs. 1-18a, *Ostrea franklini*, Coquand, p. 131, 132.

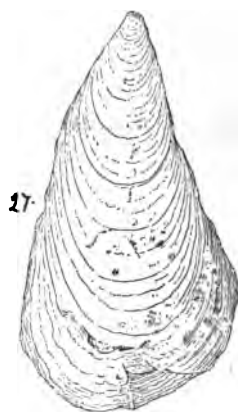
PLATE VI



19.



19a.



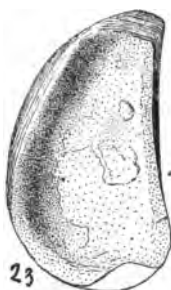
27.



20



22.



23



26a.



26



24



25.

Plate VI, figs. 19-27, *Ostrea franklini*, Coquand, p. 131, 132.

PLATE VII

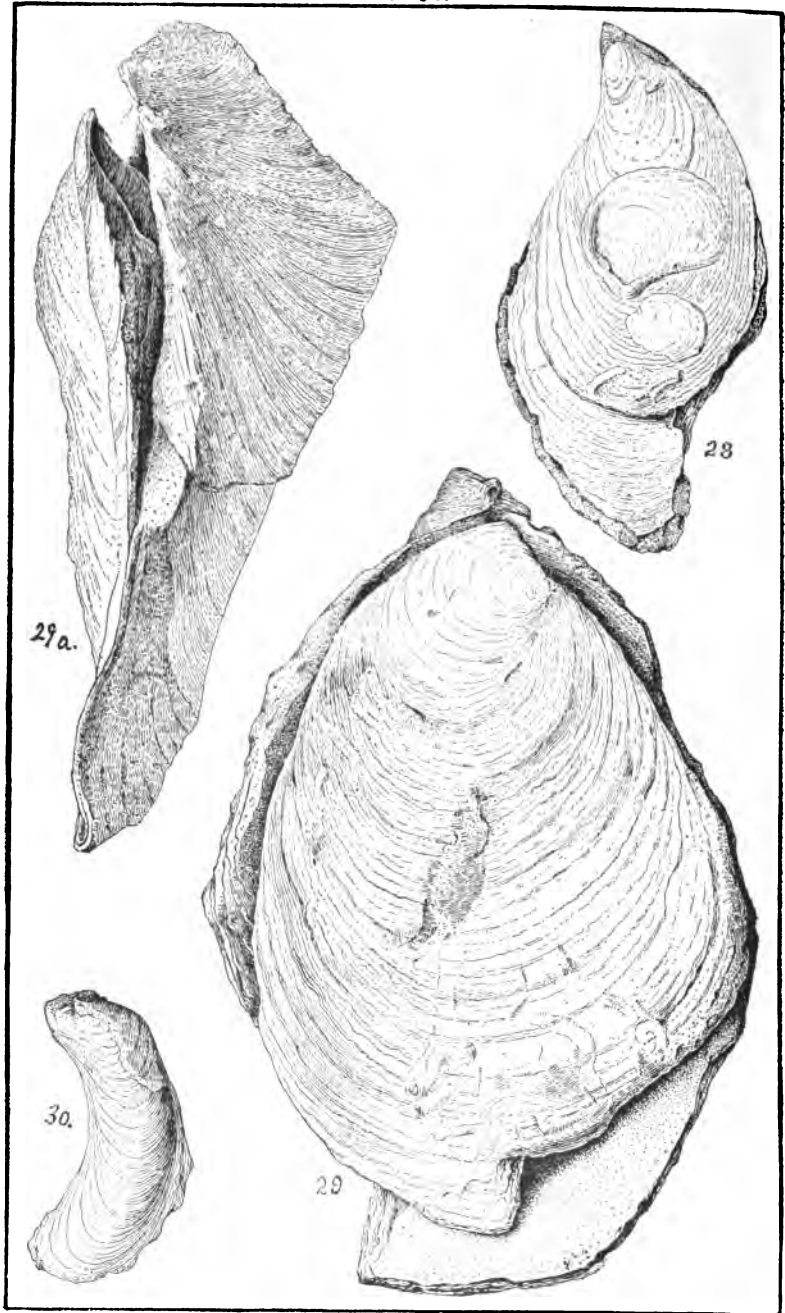


Plate VII, 28-30, *Ostrea franklini*, Coquand, p. 131, 132.

Vertebrate Remains.—The vertebrate remains occurring at the base of the gypsum bluff cannot be determined in time for this report, but will be referred to proper specialists. They all have the appearance of being saurian remains except what is probably the palatal bone of a fish, resembling the *Lepidotus mantelli*, Agg. Their general aspect, however, is corroborative of the age attributed to these beds.

Vegetal Remains.—Endeavors have been made to have the abundant vegetal remains of the Trinity beds properly studied, but Prof. F. H. Knowlton of the Smithsonian Institution, to whom they were referred, has been prevented by other duties from making the final report, which will no doubt be printed in a separate paper at an early day.*

*In a private letter to the author Prof. Knowlton says: "About the lignites you sent me, I regret that I did not have time to prepare a creditable report on them, but as I wrote you before leaving Washington, my time was so taken up with preparation for the Cincinnati exhibit that I could not complete this examination. I had made a few drawings, and intended to get enough to make one plate, but they are not finished. There was a very interesting thing in some of the clayey material. It was thickly filled with stems as you may remember. I selected a few of them, boiled them out in nitric acid, and mounted them in Canada balsam, when the structure was brought out most clearly. It is something new evidently, and so far as I could find in the time I was able to give the subject, is undescribed. I have not decided what to call it, and indeed a mere description, without accompanying plates, would be of very little scientific value. The lignite examined was all coniferous and probably of the genus *Cupress-inoxylon*, although of this latter I will not be sure. I had made drawings of it, also, but they are likewise unfinished."

CHAPTER XIV.

CHALK IN THE NORTH AMERICAN CRETACEOUS.

Although certain calcareous beds in the South have been vaguely described by American writers as "rotten limestones," and other calcareous beds of the Nebraska formation of the upper Missouri, have been exceptionally alluded to as of a chalky nature, the American cretaceous has been generally considered arenaceous, and the term chalk has been studiously avoided in lithologic description, even at the expense of much circumlocution. Explorations in the Alabama-Mississippi region and in the northwestern territories, where the lower formation is unrepresented, were supposed to confirm the late age and generally arenaceous non-calcareous character of the American cretaceous as a whole.

Investigations in this Arkansas-Texas region, where the American cretaceous is best seen, show that we have, in a general manner, the equivalent not only of the upper but also of the middle and lower cretaceous beds of Europe, while chemical, stratigraphic and microscopic investigations prove conclusively that the culminating lithologic character of each of the two grand divisions of the lower and upper cretaceous beds of the region are cretaceous (chalky) both in name and in fact. In other words, the great mass of the cretaceous rocks in America, as in Europe, are, or were, mostly composed of more or less foraminiferous, chalky, infra-littoral sediments, while the upper arenaceous beds of New Jersey, Alabama, and the northwest, are only the littoral deposits of the upper cretaceous formation and hence are exceptional, and not representative of the whole period. Indeed, the cretaceous formations of the Arkansas-Texas section are principally composed of chalks of different degrees of purity, both with and without flints, which facts throw great light upon the stratigraphic history of the cretaceous system, and prove that each of these

formations culminated in long epochs of deep sea sedimentation.

The idea that true chalk does not occur in the United States, has also arisen from the lack of personal investigations of the formations of this southwestern region. The current idea on the part of the people that the refined chalk used for blackboard crayons (which is not natural chalk at all) and otherwise employed in the arts, is typical of the natural beds of the material, and that it is almost exclusively composed of the microscopic shells of small organisms of the ocean's bed known as foraminifera, has also led to confusion. These popular opinions, no doubt, owe their origin to mistakes in our standard manuals of geology, for much of the chalk of commerce is a refined product. As for the preponderance of the shells of minute organism, upon the authority of the best European geologists, "unbroken foraminifera make up but a small part of the chalk (European) and all the fragments of these organisms together would not make up one-half the bulk of the rock." But instead, as in the Rocky Comfort beds, "prisms from the shells of *Inoceramus*, portions of *Ostrea*, *Pecten* and echinoderms are abundant, as are spines and spiculae of sponges. Fragments of Brachiopods are rare. *Coccolithes* abound."*

Before proceeding, however, it would be well to understand what is meant by the word chalk. The name has been applied to various horizons of the upper cretaceous in Europe, which correspond in geologic age, but "it is now generally admitted that no trustworthy divisions can be made, based on the lithologic character of the chalk;" hence, we must for the present use the word in its petrographic sense only. Neither is it a definite chemical compound, but a more or less variable mixture, in which carbonate of lime largely exceeds all the other ingredients. The best authorities practically agree that chalk is "an earthy, nearly pure, carbonate of lime, forming a soft white rock, soiling the fingers. In England the lower bed of the chalk contains, however, various and often larger proportions of alumina and silica. It also contains as segre-

*Manual of Geology, Phillips, Part I, Seely, p. 3.

gated minerals, flint, chalcedony, and iron pyrites, and as adventitious minerals, glauconite, quartz grains, etc. Example, the chalk of Kent and Sussex."*

Modern dredging shows that chalk, in its origin, is a moderately deep sea (not abysmal) sediment whose depositions began in past geologic ages and still continues. It is found in the neozoic formations, especially the cretaceous, in large beds, but it is probable that a large portion of the hard lime rock formations of the older periods were originally of the same nature and origin, but have been hardened by molecular change acting through a vastly greater length of time. With this definition of chalk, let us examine the stratigraphic divisions of each of the two great formations of the American cretaceous and determine whether they are chalky in character.

Historically each of these formations represents a great subsidence from land to deep sea conditions, marked by all the accompanying sequence of sediments, from littoral sands, through clays to deeper chawks, and were separated by a mid-cretaceous land epoch. The lower portion of the lower cretaceous formation (Comanche series) or first subsidence was initiated by the littoral Trinity beds, which, as the subsidence increased, were succeeded by the predominating deeper sea sediments which make it, essentially, a great chalk formation accompanied by associated flint nodules. This formation also records a great series of alternations between chalk and chalk marl beds, but its chalk beds exceed all others in the proportion of ten to one. This epoch of subsidence was succeeded by the mid-cretaceous land epoch that preceded the Dakota *sous-etage* or beginning of the upper cretaceous. Although its geographic continuity has been broken by destructive denudation, and its strata metamorphosed into limestones by local igneous action, there still remains, *in situ*, in Texas as great an area and mass of chawks or metamorphosed chawks of this formation as there is of non-chalky beds of the whole upper cretaceous formation of the Atlantic coast, or of the

*Geology, Chemical, Physical and Stratigraphical, by Joseph Prestwich. Oxford, 1886, p. 29.

late cretaceous shallowings of the northwest. The writer has traced this formation from the western border of Arkansas, where its strata are exposed only beneath the later cretaceous and quaternary deposits in the deepest ravine of Little river, to the corner of New Mexico, Texas, and Mexico, where its upturned and hardened strata form the mass of the great mountains. Wherever exposed, its fossils and stratigraphy testify to a deep sea origin and original uniform character as a more or less perfect chalk. In the scattered buttes of central Texas and Indian Territory is recorded the great extent of the original chalk formation. The capstone of the mesas and buttes, now a hard white chalky limestone, shows every transition from the purest pulverulent chalk, usually found below, to hard marble, the change being gradual and the result of aqueous solution, and crystallization, and of igneous metamorphism.

This lower cretaceous chalk occurs in great quantity and purity in certain of the buttes of central Texas, such as "Hog mountains," in Comanche county, accompanied by the most perfect nodules of flint and chalcedony which cover the hill-sides in every direction. Generally, however, as mentioned above, it has undergone metamorphism by solution and redeposition into the firm pasty semi-crystalline limestone* of the region, as seen throughout Texas, Caney creek, Indian Territory, and at Cerro Gordo, Arkansas, on the bluffs of Little river. At Painted Caves† near the mouth of the Pecos, the

*"Caprina limestone" of Shumard.

†The following extracts from Dr. G. G. Shumard's Reconnaissance attest the chalky character of this formation in that region: "In the evening we encamped near the valley of Rio Seco, which is here about a half mile wide, and bounded on the west by a range of high bluffs of nearly horizontal strata of white chalk, with flints imbedded, resting on blue marly clay, the whole overlaid by about twenty feet of drift. The chalk presents a thickness of about twenty five feet, and, although less pure, resembles in chemical composition and external character the foreign commercial article. This will doubtless prove of considerable economic importance. The imbedded flints are from one to six inches in diameter, and are scattered promiscuously through the mass. They are more or less rounded, and in color vary from light brown to deep blue and black. Fossil remains were detected in several

chalky strata are hundreds of feet in thickness, and generally of uniform character throughout.

Not only has there been solvent metamorphism, but in Franklin, Eagle and other mountains of the Trans-Pecos region and the State of Coahuila can be seen the metamorphism of these once unconsolidated chalks by igneous contact into the hardest, firmest, blue limestone, absolutely indistinguishable from the neighboring carboniferous limestones except by its fossils. The cause of this metamorphism is readily seen to be the massive and numerous eruptive sheets which appear everywhere above them. At Pilot Knob, south of Austin, Texas, the chalk of Rocky Comfort is metamorphosed into a firm crystalline limestone, almost a marble, even the shell structure of the *Exogyra costata*, var., *ponderosa*, which usually occurs unaltered, being changed into harder material. In places where the chalks were slightly arenaceous, the metamorphosed rock has a vitreous appearance. This metamorphism has been caused by the immense mass of basaltic material which has been extruded through it.

The upper cretaceous or *Exogyra costata* series, which is best known to American geologists, like the lower, exhibits a similar history and is also essentially a great chalk formation. The rocks of the Comanche series, or lower cretaceous formation were elevated above the sea level at the close of that epoch, as attested by the eroded surface upon which the Dakota sandstone and other later cretaceous beds were unconformably deposited. This emergence into a land epoch was followed by a profound subsidence, during which time the upper cretaceous formations were slowly deposited, as recorded

of them." (A Partial Report on the Geology of Western Texas by Prof. George G. Shumard, Austin, 1886, p. 63).

"The canyon here was about five hundred feet deep and a hundred yards wide. The rocks composing its sides have, in general, the same lithological character as those near the entrance. There are, however, some differences worthy of mention. Some of the layers are nearly purely white, and resemble chalk, and others near the top contain nodules of flint, with fossils and hematite, the former sometimes so abundant as to constitute a very large proportion of the beds." (Prof. George G. Shumard, op. cit., p. 73).

in the whole sequence of the upper cretaceous, from the Dakota to the Laramie inclusive, in the Texas and Rocky mountain region.

The medial part of the American upper cretaceous (Rocky Comfort chalk of Arkansas, Austin and Dallas limestone of Texas, and the Niobrara of the northwest), as seen in Texas, Arkansas, New Mexico, Colorado, Kansas, Nebraska, etc., represents the culmination of this second subsidence and is, essentially, the most extensive chalk formation of the United States. This massive bed of chalk is, in some places, 500 feet thick, and extends unbroken the entire length of the State of Texas from Red river to the Rio Grande and far north towards Canada. In Texas and Arkansas it usually contains from 88-96 per cent. of calcium carbonate, and is largely composed, as seen in microscopic sections made by the Arkansas Geological Survey and by Mr. J. S. Diller of the U. S. Survey, of shells of the foraminifera, *Textularia* and *Globigerina* predominating. It has the general lithologic character of the gray, and sometimes of the white, chalk of Europe. It has all the microscopic characteristics of commercial chalk, and the topographic features of the region it underlies greatly resemble those of the chalk downs of England. In the humid portion of its region, Arkansas, Indian Territory and the Black Prairie of Texas, the chalk decomposes rapidly on exposure, but in the more arid portions, as at San Antonio, it indurates so that the chalk, which, when fresh from the quarries can be easily worked with ordinary tools of the carpenter, soon hardens into a lasting building material.* There are one or two chalky horizons above this main bed, as at the White Cliffs of Little

*According to Professor Viala, the French agriculturist, "the sub-soil of the region is a white chalk, crumbling and of variable durability, but always soft, having generally a texture intermediate between the tufaceous chalk and the chalk proper (*craie blanche*), of Champagne." Report to the Minister of Agriculture by M. Pierre Viala, Professor of Viticulture, at the National Agricultural School, Montpellier, France.

river,* but, in general, its succeeding beds, of over a thousand feet, pass through chalk marls into sands.

Although the middle portion of the upper cretaceous series section of the Gulf and Atlantic slope also show some chalky horizons, such as the Rotten limestone of Mississippi, all of the succeeding upper cretaceous sediments, from the basal chalk just mentioned, to the latest beds we have preserved, as represented in the greensands of New Jersey, present a definite record of long continued deep sea history and final emergence.

The "chalkiness" of the whole upper cretaceous series decreases by imperceptible transitions from more than 95 per cent. to less than 10 per cent. of carbonate of lime, the siliceous matter increasing in proportion. These transitions are seen, first, in the yellow lime marls which greatly resemble the calcareous-globigerina ooze of the present ocean, and finally in the glauconitic (Washington, Ark.), sands, showing a gradual shallowing and elevation through thousands of feet of sediments from deep sea conditions to moderate depths, including the impure chalks known as "rotten limestone," which caused Sir Charles Lyell erroneously to characterize the whole of the American cretaceous when he said:† "So little do they resemble mineralogically the European white chalk, that in North America, limestone is upon the whole an exception to the rule; and, even in Alabama, where I saw a calcareous member of this group, composed of marl-stone, it was more like the English and French Lias than a European secondary deposit."

Upon examination of the following analyses of Arkansas upper cretaceous chalks, and comparison with those given of European and Texas material, the interesting conclusion can-

*A remnant of, perhaps, the most remarkable and beautiful chalk formation in America occurs about half way in this section at the White Cliffs of Little river, Arkansas, where a bluff of pure white chalk over 100 feet in height outcrops along the river's edge. Its original thickness and extent has been reduced by the grinding of the later gravel beach that surmounts it.

†Elements of Geology; Sir Chas. Lyell, New York, 1866, p. 339.

not be avoided that the rocks are as much entitled to the name chalk as those of Europe. The analogy is especially close between the lower chalk of Europe and the Rocky Comfort beds, which, paleontologically are probably of the same age:

	Lower Cretaceous chalk, Burnet Co., Texas. (1).	Upper Cretaceous chalk, Rocky Comfort, Ark. (1).	White Cliff chalk, Little River, Ark. (1).	White chalk of Shoreham, Sus- sex, England. (2).	Grey chalk, Folk- stone, England (2).
Carbonate of lime	96.42	88.48	94.18	98.40	94.09
Carbonate of magnesia	1.88	trace.	1.37	0.08	0.81
Silica and insoluble silicates	1.59	9.77	3.49	1.10	3.61
Ferric oxide and alumina	0.41	1.25	1.41		
Phosphoric acid, alumina and loss				0.42	trace.
Chloride of Sodium					1.29
Water	0.18		0.55		.70
	99.98	99.50	101.00	100.00	100.00

(1.) Analyses by the Geological Survey of Arkansas.

(2.) Analyses by David Forbes.

"These (English) analyses show the proportion of carbonate of lime in the upper and lower beds, but probably of selected specimens. Were an extensive mass of chalk analyzed, the amount of silicate of alumina might prove larger."* Arkansas and Texas specimens were not selected, but, upon the contrary, were picked up from the surface where the conditions had been favorable for the solution of much of the carbonate of lime, and without intending to have them analyzed. The specimen of the lower (Comanche series) chalks from Burnet county, Texas, analyzed for this occasion, show that its purity is even greater than that of the upper cretaceous.

If the upper cretaceous of the United States was predominantly chalky or foraminiferous in its origin, why has the fact so long remained unrecognized? To this question the brief answer can be made that only the littoral areas or margins of the American cretaceous have heretofore been examined systematically. It can also be said that at some point later than the Niobrara epoch, a differentiation set in between the characters of the sediments in what are now the Rocky Mountain and the Atlantic-Gulf regions, culminating in the

*Woodward, op. cit., p. 395.

more shallow deposits of the former, while deep water conditions continued for the most part in the latter. In the former, by a system of favorable conditions which has made the whole geologic section of that region more susceptible of interpretation, this shallow condition of deposits is clearly recorded.

In the heavily timbered Atlantic seaboard, however, where the deep marine (Rocky Comfort) phase of the upper cretaceous formations was developed, outcrops are not only scarce, but there have been so many subsidences and such destructive erosion and lixiviation during later periods, that what we now see in our greensands, "rotten limestones," etc., are only remnants, and the final phenomena of the great chalk forming conditions. It is also probable that the whole stage which may have represented the very latest European cretaceous (Maestricht) in eastern America, may have been removed by the erosion of the post-cretaceous continent and the subsidence during the deposition of the tertiary, the sediments of which are deposited upon an unequally eroded cretaceous contact.

Another popular error concerning chalk is that it must be accompanied by flint nodules, which are rare in the Niobrara chalk of the Northwest and the Dallas chalk under discussion, which may be its southern representative. But according to Woodward: "It is now generally admitted that no trustworthy divisions can be made (of the chalk) upon the abundance, rarity and even absence of flint nodules."* Nodules of the purest flint do occur in the American chalks, however, not in limited quantities, but in such abundance and beauty that great areas of central Texas, particularly at Austin and in northwestern Comanche county, are covered with them and their fragments. These nodules have been exposed by the denudation of the softer chalk beds in which they occur. They can be seen in immense quantities *in situ* in the adjacent buttes. In the same region the same chalk as that which composes the Rocky Comfort beds is covered in many places by tons of flint which has either been transported from the lower chalk

*Geology of England and Wales, 1887, pp. 400-401.

horizons of the Comanche series to the westward, or it marks the remnants of its former thickness.* Until the quaternary and tertiary history of our continent is revealed, the former extent of the American chalk cannot be appreciated.

There is no exact synchronism in lithologic features between the minute subdivisions of the cretaceous of Europe and America, nor would it be expected in beds so far apart. In the light of modern deep sea explorations, however, it may not be unwise to predict that these deep sea sediments formed at the same time, beyond littoral influences, in the bottom of the same deep ocean, may some day be found to be related more intimately, genetically, than has hitherto been supposed.

*The flint nodules of the lower cretaceous often have a nucleus, which is generally the fossil *Caprotina lonsdallii*.

CHAPTER XV.

RESUME OF THE CRETACEOUS GROUP.

In the earlier days of American geology, before the Arkansas-Texas region had been explored, two misconceptions arose concerning the cretaceous formations. The first of these was that there were no marine strata in the United States comparable to the middle and lower cretaceous strata of Europe. The second misconception was that the cretaceous formations of this country were conspicuously devoid of chalk deposits, and hence, exceptional by the absence of what is its most characteristic litho-paleontologic feature in other parts of the world and from which the name of the group is derived. These opinions were the logical result of what was then known of the American cretaceous formations. Knowledge of this group was at first mostly confined to the strata of New Jersey, which, although devoid of any chalky material, are, as shown by their fossils, equivalent* to the upper chalks of Europe. The New Jersey deposits were also supposed to represent, stratigraphically and faunally, the whole American section, but, in fact, they are only the uppermost beds of the upper division of the American cretaceous, and in no manner reflect the great development of the lower beds in the southwest. They are the last and more shallow portion of the long continued deep sea subsidence which deposited the chalky strata of the southwest, which strata were not deposited in the New Jersey area at all.

The first of these misconceptions, which has been but recently dispelled, must now, in the light of the section presented in this paper, be abandoned, for here we have shown in this Arkansas-Texas section not only the presence in America, as well as in Europe, of the most perfect representatives of the extremes of the cretaceous group (the upper beds of the upper cretaceous series), and the Trinity beds [Wealden], but a great

*In the paleontologic sense that their fossils are similar.

series of intervening beds which record a connected history of its principal events.

It would be impossible to introduce here more than a small portion of the paleontologic proof by which this proposition is demonstrated. The stratigraphic proof has already been given in the preceding pages. A careful revision of the synonymy of our American cretaceous fossils would reduce one-half the species which have been disguised under a new and confusing nomenclature, to their European synonymy, and a study of their stratigraphic and faunal associations would reveal an orderly and interesting succession, which can be illustrated by an analysis of the occurrence of the forms of any single family, such as the *Echinodermata*, *Ammonitidæ*, *Ostreidæ*, etc.

The cretaceous *Ostreidæ* of this country, although the best preserved, the most abundant and the most conspicuous of our fossils, are but little understood, and their stratigraphic occurrence has not even been published. Their study, until late years, has been accompanied by difficulties. No satisfactory generic classification has been agreed upon by naturalists, and individuals of all species have such great variation that specific differentiation, based upon the material studied at second hand has been almost impossible. The chief difficulty, however, has not been that of classification, but that there has been but little opportunity to study the fossils in the beds containing them. In other words, the data concerning their habitat and variations have been insufficient, which fact, as in any other branch of natural history, has given rise to much hypothesis, and resulted in the establishment of many superfluous species.

In European countries, on the other hand, where many scientific centers are convenient to an abundance of mesozoic material, the nomenclature of the fossil *Ostreidæ* has greatly increased and confused the ultra-stratigraphists, who, upon finding a species with great vertical range, such as the *Ostrea flabellata*, Goldfuss, have given it a new name for each horizon, on the ground that while there was no perceptible difference in the appearance of the specimens, they could not be

the same species because they occurred in different stratigraphic horizons.*

Our older American paleontologists, on the other hand, for the most part, were located far from the great development of the cretaceous group, and have been little acquainted with its stratigraphic divisions or the range and variations of their contained species. This has resulted in creating many erroneous species upon the insufficient data of few and imperfect specimens sent from regions which their authors had never seen, and in the application of many names to the same species.

It has been the writer's fortune, during years of residence and observation in the Arkansas-Texas region where the American cretaceous is best displayed, to study its entire vertical range, and to note the variation and stratigraphic occurrence of its abundant molluscan fauna. While agreeing with accepted authorities that the variation in shape is generally so great in the fossil oysters as to make specific differentiation difficult, my own observations lead me to restrict these difficulties to the genus *Ostrea* proper. No other fossil molluscan form is so numerous, so favorably preserved for study, or of such conspicuous criterional stratigraphic value as certain species of the artificial sub-genera, such as *Exogyra*, *Gryphæa*, *Alectryonia*, etc. Some of these characteristic forms, common to both Europe and America, such as the *Ostrea flabellata*, *Ostrea frons* and their synonyms, have great vertical range and variation, while others, like the Texan *Exogyra arietina*, for which the writer has found no analogue elsewhere, appear by the millions in a single definite stratigraphic horizon only.

The stratigraphic occurrence and range of the principal unmistakable species I have represented on the accompanying diagram without attempt at reformation of their synonyms. It must be remembered that there is one great nonconformity in the cretaceous which may account for the abrupt appearance and disappearance of some of these forms, but with others their appearance and disappearance can only be explained by the varietal changes due to long periods of time.

*Paleontologie Francaise, Vol. III, p. 703.

Nearly all of these species are of wide occurrence on both sides of the ocean, or have very close trans-Atlantic identity affinities :

	Jurassic? (Tucumcari beds)	Transitional Jura-cretaceous	Comanche series, Fredericksburg division.	Comanche series, Ouachita division.	Base of Rocky Comfort chalk (Dakota-Niobrara epochs).	Rocky Comfort chalk.	Exogyra ponderosa marls.	Exogyra costata greensands.	Middle Marl bed of New Jersey.
<i>Exogyra costata</i> , Say.....							X	X	.....
<i>Exogyra costata</i> , var. <i>ponderosa</i>								X	.....
<i>Ostrea larva</i>								X	.....
<i>Gryphæa vesicularis</i> , Lamck.....					X	.....	.....	.....	.....
<i>Ostrea bellaplicata</i> , Shum.....									
<i>Exogyra arietina</i> , Roem.....				X	.....	.....	.....	.....	.....
<i>Gryphæa sinuata</i> , Sow. (Mor).....				X	.....	.....	.....	.....	.....
<i>Ostrea subovata</i> , Shum.....				X	.....	.....	.....	.....	.....
<i>Ostrea diluviana</i> , Lamck.....				X	.....	.....	.....	.....	.....
<i>Gryphæa pitcheri</i> , dilate var. Hill (not Marcou) ..				X	.....	.....	.....	.....	.....
<i>Gryphæa pitcheri</i> , forniculate var., White ..				X	.....	.....	.....	.....	.....
<i>Gryphæa pitcheri</i> , type var., Morton ..			X	.....	.....	.....	.....	.....	.....
<i>Ostrea flabellata</i> , Goldfuss.....			X	.....	.....	.....	.....	.....	.....
<i>Exogyra texana</i> , Roem.....			X	.....	.....	.....	.....	.....	.....
<i>Ostrea franklini</i> , Coq.....		X	.....	.....	.....	.....	.....	.....	.....
<i>Ostrea marshii</i> , Marcou.....	X	.....	.....	.....	.....	.....	.....	.....	.....
<i>Gryphæa dilatata</i> ? Marcou	X	.....	.....	.....	.....	.....	.....	.....	.....

For further illustrations let us critically examine two well marked species, one a characteristic fossil of the *Exogyra costata* series, and the other of the Comanche series.

Exogyra costata, Say, and its Variety, *ponderosa*, Roemer.—

This is the big oyster and its varieties so numerous and characteristic of the Hempstead county black lands. It is the largest, the most widely distributed and the most conspicuous fossil of the American upper cretaceous. It occurs in the beds of the Atlantic slope, from New Jersey to Mexico, and westward from Eagle Pass, Texas, on either side of the Mexican border, to California. Not only is it found in America, but it is also common in Tunis, Tripoli, Sicily and Syria, where it is characteristic of the upper greensand.*

**O. overwegi* and *O. fourinette*, Coquand. Etage Rhotomagienne. Memoires de la Societe d'Emulation de la Provence Geologie et Paleontologie de la Provence de Constantine par M. H. Coquand. Tome II, Plate XIV, Fig. 1, 2. Atlas Marseilles, 1862. Figures *O. overwegi*, H. Coquand.—*E. costata*, Plate XIV. 1, 2. *O. fourinette*, H. Coquand Plate XXI,—*E. ponderosa*. *Natica elatior*, H. Coquand.

In New Jersey, from whence it was originally described, its typical or costate variety occurs in the lower marl beds in abundance. This variety reaches its greatest culmination in the upper or arenaceous beds of the states of Mississippi, Alabama, Tennessee and Arkansas, in the strata which Dr. Hilgard has described under the various names of "Tombigbee sands," "rotten lime-stone group," and "Ripley group," and which are spoken of collectively in this paper as the upper cretaceous or *Exogyra costata* series. The more ponderous, unribbed variety (*E. ponderosa*, Roemer) is more characteristic of the marly and chalky beds of the lower half of the series. In southwestern Arkansas, the huge individuals are so plentiful that in many places they are gathered by the tons and burned for lime, or used for cobblestones.* The type form of this species is beautifully costate or ribbed, as are many of the specimens found in this state, from which fact it received its specific name. These ribs are not always present, either in the young or in the adult stage, and are insufficient for specific determination,† as I shall presently show. In 1848 Dr. Ferdinand Roemer,‡ the distinguished German paleontologist, found in southern Texas a huge *Exogyra* resembling the *costata* in every respect, except that the ribs were absent, thereby rendering the transverse corrugations, which are common to both forms, more conspicuous. My observations in the region where he collected his specimens, convince me that with the material at

*The author saw over 1000 individuals arranged in a pavement in southern Howard county.

†Some authors regard *Exogyra ponderosa*, Roemer, as only a variety of *E. costata*, differing only in the absence of the costae. This feature is so constantly present in the one form and absent in the other that I regard them as representing different species. White: Fossil *Ostreidae* of North America, p. 304. The massive form (*E. ponderosa*), as before remarked, has been regarded by some authors as not specifically different from *E. costata*, Say. The two forms are certainly closely similar, but their surface characters are apparently constant in their difference, even when they are found associated in the same stratum. The lower valve of ponderous species is very massive in old examples, sometimes reaching nearly two inches in thickness of solid shell substance. White: Op. cit., p. 306.

‡Kreidebildungen von Texas, p. 71.

hand, and at that time, he was justified in giving this type the new descriptive specific name of *Exogyra ponderosa*—an opinion which is upheld at the present time by standard authorities. Similar observations in the Hempstead county black lands and in the middle states of the gulf region, however, where both the New Jersey costate variety, and the Texas ponderous variety, occur in the greatest abundance, show that while the *ponderosa* is characteristic of the lower and the *costata* of the upper beds, every transition exists between the two alleged species in the medial beds, as seen in thousands of individuals, proving that specific separation is no longer justifiable. Not only is this visible in specimens from the Gulf States, which is the region of their greatest abundance, but in the extremes of New Jersey and Texas, as is illustrated in Mr. Whitfield's figure in his work on the "Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey." This figure illustrates the characteristic features of both varieties.

- It is true that the ponderous variety is most frequently found in the lower loose calcareous marls, and the costate in the upper and more arenaceous beds, but careful observations show that there is perfect transition between them, and that it is especially noticeable in the transitional beds between the calcareous and arenaceous marls. Many young forms of the costate variety have been described under a dozen names, but I have often picked out suites showing every characteristic of each of the dozen species described. This form has never been found
- in the Comanche series of beds, or lower cretaceous formation.

Gryphæa pitcheri, Morton.—The second cretaceous oyster chosen as an illustration of the variation, is the *Gryphæa pitcheri*,* Morton, which is characteristic of the lower cretaceous formation. This species has such a striking jurassic aspect, that it has been the object of more controversy than any other form from the American cretaceous. Most of this controversy, however, has been among paleontologists who have

*Syn. Org. Rem. Cret. Pl. XV, Fig. 9, Philadelphia, 1834.

never seen it in place, and hence could form but a slight idea of its variations and stratigraphic relations. It was first named and described at Philadelphia some two thousand miles from its easternmost locality, in the earlier days of American geology, and all the discussion concerning it has been upon the part of scientific men, most of whom have never been much nearer to it than they were when at Philadelphia, and the figured type specimen gives no idea of its many variations.

Instead of having been originally described from New Jersey, as has been asserted in our best work on the American Fossil Ostreidæ,* it has never been found east of the present locality near the Arkansas-Choctaw line, except, perhaps, in those anomalous outcrops, the salines of Louisiana.† The young of *Gryphæa vesicularis* has often been mistaken for it in Mississippi. It occurs in the central denuded region of Texas, Indian Territory and southern Kansas; in northern Coahuila, Chihuahua and Sonora, Utah, New Mexico, and perhaps Colorado, also South America and Mexico. It ranges from the bottom to the top of the Comanche series, occurring in many horizons, each of which may contain all of its diverse varieties, but some of them conspicuously preponderating. The number of these fossils and the length of geologic time during which they grew are so great as to be incalculable. Besides the minor zones, which, elsewhere than in Texas, would be considered wonderful displays of ostreidean life, there are two great strata of oyster breccia. The lowest of these which I have previously published as the "horizon of *Gryphæa pitcheri*, with *Exogyra matheroniana*," (*E. flabellata*, Goldfuss), is a perfect mass of the shells of *Gryphæa pitcheri*. The bed averages forty feet in thickness, and has a longitudinal extent, so far as observed, of over 250 miles, from the Colorado river in Texas,

*C. A. White, Fossil Ostreidæ, p. 303. Fourth Annual Report United States Geological Survey.

†Varieties of the *G. vesicularis* and *E. costata*, in Alabama, Mississippi and Texas have frequently been confusingly termed *G. pitcheri*, but after most painstaking endeavors and study of the faunas of those regions I have failed to authenticate a single reference of *G. pitcheri* in the upper cretaceous.

northward through the town of Weatherford, into the Indian Territory, and thence to the Arkansas line. Several hundred feet stratigraphically above this horizon there is another culminating zone, which I have called the "horizon of the *Gryphæa pitcheri*, with *Ostrea carinata*," in which this fossil also appears in inconceivable numbers, but the prevalent variety is different, and accompanied by many faunal changes, showing that the species has persisted, while many of its former companions have become extinct. In the intervening strata between these culminating horizons, thousands of individuals are found, but I have as yet failed to find a bed where with moderate assistance from the imagination, a suite of specimens could not be gathered showing nearly all the varieties which have been raised to the dignity of species upon what must be considered insufficient data.

As has already been mentioned, the original type of *Gryphæa pitcheri* was established by Dr. Morton, in 1834, upon rather poor specimens, brought from the Kiamesha plains and falls of the Verdigris, in the Indian Territory, which was, at that time, a portion of Arkansas. Dr. Morton's brief description gives no stratigraphic data, for he had never seen the country from which the specimens were gathered by Dr. Pitcher, an army surgeon.

In 1848 Dr. Ferdinand Roemer studied a limited portion of Texas, some 400 miles south of where Dr. Morton's specimens were collected. He did not know of the stratigraphic continuity which has since been established between them. In the vicinity of New Braunfels, at the very top of the lower cretaceous formation, he found the variety shown in his figures* upon which he remarked that this peculiar shell having the aspect of *Gryphæa arcuata* of the Lias, belonged to a jurassic type that had never been found in the cretaceous, and that he could never have recognized from Morton's imperfect figure, which represents either a young or small form, that the great swollen, boat-shaped example from Texas belonged to it, if he had not seen Morton's type examples, identified by

*Kreidebildungen von Texas, Plate IX., Figs. 1a, 1b, 1c.

himself, in the Museum of the Academy of Natural Sciences at Philadelphia. Besides, Morton himself remarks in his original description that he had an imperfect example almost three inches in length. (Kreide. von Texas, 72-73).

A few years later Mr. Conrad first suggested that the *Gryphæa pitcheri* had two well marked varieties, which occurred in distinct horizons, and proposed for this one figured by Roemer, the name of *Gryphæa pitcheri*, var. *navia*, a proposition in nomenclature for which he deserves much credit, especially when it has been remembered that he never visited the region where the fossils are found.

In 1852 Mr. Jules Marcou crossed the Indian Territory east and west, near the Texas line, and later figured the specimen which is given in his Geology of North America, Plate IV, figs. 4, 5 and 6. His evidence is worthy of consideration, for, besides Roemer, he is the only geologist writing upon the species who had an opportunity to observe their natural occurrence. He says: "This species is found in the first cretaceous rocks in Texas, where it is as numerous as the *Gryphæa arcuata* in the Jura mountains and the Wurtemberg Alps. The limestone of the False Washita and the Canadian river might be called with propriety gryphite limestone.* These beds being the lowest of the cretaceous rocks of Texas, and the form of the *Gryphæa pitcheri* having more resemblance to the *Gryphæa couloni* than any other species, have led me to consider these strata as the equivalent of the Neocomian group of Europe." (Geol. N. A., pp. 38-39).

The variety which Mr. Marcou figures (fig. 3) is not the same as that originally given by Morton, but it is nevertheless, the same species, for Mr. Marcou no doubt saw, as the writer has seen a thousand times, the complete gradation of this variety into Morton's type. The specimen has a sharp, carinate back, and the the beak deflects a few lines from the limit allotted to the artificially constructed *Gryphæa*, in a direction which, we are informed, makes it an *Exogyra*. It is unfortu-

*I have good reason to believe this the continuation of the extensive lower *Gryphæa* bed above mentioned. (R. T. H.)

nate to see the varieties of a species changing from one genus into another, but such is the case with the *Gryphæa pitcheri*, the fault being, as above mentioned, that the generic distinctions between *Exogyra* and *Gryphæa* are artificial and unreliable. This variety (?), figured by Marcou, is very common, especially in the argillaceous beds. In 1880 it was again described as a new species by Dr. C. A. White, under the name of *Exogyra forniculata*, upon the evidence of specimens sent to the National Museum,* but my own observations convince me that its specific identity can no longer be maintained. A comparison of the figures and descriptions of Messrs. Marcou and White leaves no doubt as to the identity of the variety which they discuss.

Still another well marked variety greatly resembling the *Gryphæa pitcheri*, and differing greatly from those I have presented, was identified by Mr. Marcou as the *Gryphæa dilatata* (fig. 1), and so maintained by him and others until this day. Laboring under the mistaken impression that I had found in Texas, notably at Denison by the millions, in the upper gryphite bed which I have mentioned above, many forms agreeing with his smaller and imperfect figure 1, and grading into the original, typical *pitcheri* on every hand, I erroneously assigned it to that horizon. Judging from the figure there was much reason to doubt its specific independence. It was with reluctance that the writer thus disagreed on the specific value of this form with Mr. Marcou, who was the first geologist to intimate the true significance of the Texas cretaceous, and whose opinions thereon had been unfortunately disregarded by American geologists who had not visited this Texas region. During the month of August, 1888, for the purpose of ascertaining the exact truth of this disputed point, the writer visited Mr. Marcou's typical locality of Tucumcari mountains, in New Mexico, and found that the *Gryphæa dilatata* occupies a definite horizon, occurring by thousands, far below what had hitherto been supposed to be the base of the American cretaceous, where the small and entirely different

*Proceedings United States National Museum, Vol. II, 1879.

typical variety of *Gryphæa pitcheri*, Morton, usually abounds. For thirty years the observations of Mr. Marcou have suffered the disapproval of American geologists on this point, but I am inclined to believe in the correctness of his position. Capt. C. E. Dutton* in his paper on Mount Taylor and the Zuni Plateau, has already briefly admitted the correctness of this pioneer's observations west of the Rio Grande, and has placed upon the map for the first time the jurassic strata of which Mr. Marcou was the discoverer. The writer can vouch, even more strongly, for their relative correctness east of that stream.

This broad dilate jurassic *Gryphæa* of Marcou may nevertheless be the antecedent of the *Gryphæa pitcheri* of Morton,† but specimens from the typical horizons are entirely distinct.

Such are a few varieties of this anomalous fossil which has caused so much discussion among paleontologists, and which is the most abundant and characteristic fossil of the lower formation of the American cretaceous. If its variation in shape, from the narrow naviculate variety to the broad, dilate variety found at Denison, Texas, is extraordinary, its variation in size from one-half inch to three inches in length is also unusual, but if these variations seem improbable, one need only visit the piles of oyster shells along any seaport wharf and notice the tenfold greater variation in our common oyster. Many will ask, if the differences upon which these species were founded are not sufficient, where shall we draw the line? Theoretically all species are but varieties of the great arche-type. Let no fossil species—at least of living genera—be founded upon any less criteria of hard parts than one would

* "The want of a good topographic map prevented the greater degree of accuracy which Mr. Marcou would otherwise have given to his delineations, but the material for making one did not then exist. He has shown much skill and acumen, and the modifications which fuller and more detailed information, with much better maps, requires us to make in his conclusions, are not radical," (C. E. Dutton, Mount Taylor and the Zuni Plateau, Sixth Annual Report United States Geological Survey, Washington, D. C., 1885, p. 123).

† The specimen figured as *G. pitcheri*, Morton, in Dr. White's Fossil Ostreidæ of North America, is a much better picture of *G. dilatata*, Marcou, than of Morton's type variety, no figure of which appears in that work.

found a living species; let species making be secondary to the desire to make science intelligible, and apply the principles of modern biology to the life of the past as well as that of the present. The confusion of this form here mentioned is but a sample of that surrounding many conspicuous American cretaceous fossils, especially the *Echinodermata*, *Inocerami*, and *Ammonitidæ*.

CHAPTER XVI.

EVENTS RECORDED IN THE NEOZOIC DEPOSITS OF SOUTHWESTERN ARKANSAS.

Reviewing the neozoic stratigraphy of this southwestern or Arkansas-Texas region described at length in the foregoing pages, it is evident that it embraces a great diversity of geologic features, which are inconsistent with the hitherto accepted ideas of the region. Here we have a system of mountains or remnants of a system extending from the Ouachita at Rockport in Hot Spring county to west of the 100th meridian in Texas, or over eight degrees of longitude, which has never been represented as such upon our maps, but only as unconnected and meaningless fragments, and only recently named the Ouachita system by the State Geologist. Yet the geologist who observes it as a whole, whether as the high and projecting ridges of Arkansas, the isolated Navajos and Wichitas of the Texas Pan-handle, or as the intervening "potato hills" of the Chickasaw Nation where its continuity is almost lost, cannot but realize the entirety of the system, and see in the remnantal protuberances of this ancient mountain system a feature which presents a partial solution of many problems in the southwest. These mountains have been the eastern and northern barriers to the immense sedimentation of late paleozoic and mesozoic deposits from the carboniferous to the upper cretaceous, such as the permian, triassic and lower cretaceous, whose existence has been so little known that to-day a large number of our best American geologists are on record as having denied their presence.

The formations of this southwestern section do not constitute a continuous series of sediments representing the gradual receding of the waters of the present Gulf of Mexico from the older continental shore line, but are each separate and distinct one from the other, between each of which there are complete

stratigraphic and faunal breaks, representing a perplexing alternation of subsidence and elevation. Beginning with the lowest in Arkansas these formations, in ascending order from the paleozoic rocks, are as follows :*

I. The Trinity Division.—The Trinity or basal division of the cretaceous is a littoral formation whose characteristic fossils, sands, clays and arenaceous, not chalky, limestones show it to have been deposited in moderately shallow, brackish waters along the ocean's border. This Trinity is the gypsum bearing formation and marks the beginning of the first cretaceous subsidence.

II. The Comanche or Lower Cretaceous Series.—This is a series of metamorphosed chalk (hard limestone) beds whose rocks were formed for the most part, at moderate depths in the open ocean, where the molluscan fauna mingled freely with the foraminiferal ooze. This is the formation of the prairies and buttes of the denuded country of Texas west of Fort Worth, Austin, of Indian Territory, east of the 99th meridian and between the mountains and Red river, and much of the disturbed mountains of the Trans-Pecos region. In Arkansas it only occurs beneath the plateau gravel in the valley of Little river at Cerro Gordo, and its northern border was undoubtedly the southern slope of the great Ouachita mountain system. How much of it has been denuded it is impossible to estimate. From the identity of its numerous fossil forms there can be no doubt that it is paleontologically synchronous with the lowest and lower middle cretaceous of Europe, including the Turonkreide and marine Neocomian.†

*The pre-Trinity, Permian and Jura-Trias beds of northwest Texas do not occur in the Arkansas section.

†The writer does not wish to make a detailed correlation of the cretaceous of America and Europe, but there are certain facts which cannot be overlooked in this connection. Especially is this parallelism noticeable in the fauna of the undescribed Shoal creek beds of Austin, Texas, from which Dr. Ferd. Roemer has recently described several "Juromen" fossils, and from which the writer has many more, such as are indistinguishable from *Janira fleuriansiana* D'Orb. *Acteonella gigantea*, Sow., *Pterocera*, and other forms. This stratum, as recently seen by the writer, is intercalated between the hitherto known beds of the upper and lower cretaceous.

III. *The Upper Cretaceous or Exogyra Costata Series.*—

The upper cretaceous or *Exogyra costata* series is a great chalk and greensand formation whose beds have been deposited in water which passed gradually from deep to shallow during the process of the deposition of the materials. The series is composed of sands and clays at its base, soon succeeded by massive chalk beds, as is shown in the Rocky Comfort chalk, and this gradually becomes marly, then sandy towards its top. The *Exogyra costata* or big oyster is its characteristic fossil. This is the great black land and greensand formation of central Texas, of Hempstead, Clark and Howard counties in Arkansas, and the interior coastal cretaceous lands of Tennessee, Alabama, Mississippi and New Jersey, and probably the deep water continuation of the more shallow Pierre and Fox Hills beds of the northwest.

IV. *The Camden Lignitic Series or Basal Tertiary.*—This is peculiarly a laminated micaceous sand and lignite bearing formation, of southwest Arkansas and northeast Texas, and is characterized by its alternating stratification of sands and clays. It represents the beginning of the tertiary group of strata, which are more fully developed coastward in eastern Arkansas, Louisiana, Mississippi and Alabama. It is a shallow water semi-estuarine marine deposit. Its principal area is east of the St. Louis, Iron Mountain and Southern railway.

V. *The Post-Tertiary or Quaternary Deposits.*—Every part of this whole southwestern region, from the Rio Grande of New Mexico to far east of the Mississippi river, except the highest mountains, shows evidence of one or more post-tertiary submergences and denudations. The post-tertiary deposits, beginning with the oldest, are:

First—The ancient plateau gravel, void of all organic remnants, which borders the present mountain system. It is the counterpart of a similar and symmetrical formation east of the Mississippi, which is now at an elevation of some 600 feet above the sea level. The great plains (Llano Estacado) loams which have been elevated thousands of feet in post-tertiary

and recent times, may prove synchronous with the plateau gravel.

Second—A second and later phase represented in the Prairie d'Ane clays, gravels and sands, and the *tierra blanca* of the Canadian, Rio Grande and Pecos benches, which may prove to be corollary phenomena with Hilgard's Port Hudson beds of the lower coast.

Third—The mastodon bearing loams and terraces of all the coastal and central counties of Texas from the Pan-handle to the coast, and finally a series of later coastward phases which no attempt has been made to interpret. These phenomena represent many changes of level and the degradation of an incalculable thickness of older sediments.

Evidence of Stratigraphic Breaks.—The evidences that this geologic section is not of continuous and conformable deposition, but that there are several complete stratigraphic breaks between the several series, are as follows :

(1.) *Paleontologic.*—Each formation or series has a distinct, characteristic, specialized fauna of many criterional species, which do not merge or graduate into the faunas of the underlying or the overlying series. In fact not a single species has been found to pass from one series to the other, and in harmony with the stratigraphic evidence there is a complete faunal break between each formation. This opinion is contrary to a preconceived one that the conditions would be otherwise.

(2.) *Stratigraphic.*—Distinct stratigraphic nonconforming contacts have been found between each of the formations. The great quaternary gravel deposit rests unconformably upon every horizon of all the underlying formations, and, as enumerated on pages 40-42, the contacts are frequent and clearly shown. The Camden series (basal tertiary) can be seen at Arkadelphia and the Big Deciper bluff in Clark county, resting unconformably upon the upper cretaceous series. The several horizons of the upper cretaceous rest successively upon the paleozoic at the mouth of De Roche, upon the Wolf creek Trinity beds near Antoine, and still further south upon the Comanche series, the typical contact being the Austin-New Braunfels

nonconformity between these two points in Texas. The lower cretaceous or Comanche series, with its basal Trinity beds, are deposited everywhere in Arkansas upon the almost vertical paleozoic beds, while in Texas they rest upon different formations at different places.*

(3.) There is a distinct difference in strike, direction and angle of dip of each of these formations. The Trinity dips sharply south; the upper cretaceous southeast; the Camden series east, and the gravel plateau southward—differences which cannot be understood until the orogenesis of the country is studied.

THE AGES OF THE DIFFERENT FORMATIONS.

Much might be said concerning the age of these formations and their relation to similar formations elsewhere. If the occurrence of similar fossil species sufficient to constitute a fauna furnishes data for correlation, then these formations testify much concerning their relationship with the rest of the world, which is further strengthened by an accompanying similarity in lithologic and environmental conditions and often by direct geographic continuity.

The Trinity Division of the Lower Cretaceous.—The fossils of the Trinity are peculiar to the brackish water of the Wealden and Purbeck beds of Europe, and have never before been recognized in America. These beds are probably allied to the basal cretaceous or upper jurassic, Potomac and Tuscaloosa formation of the Atlantic slope, and allied to the jurassic ("Atlantosaurus beds") of Colorado and Wyoming.

The Fredricksburg Division.—The author's observations of this horizon in Arkansas serve only to emphasize his published opinion thereon; namely, that they are much older than what had been heretofore accepted as the base of the Western American cretaceous (the Dakota group of Meek and Hayden), and are the equivalents of the lower cretaceous (upper

*See American Journal of Science, October, 1887, pp. 290-296.

Neocomian) of Europe instead of the upper, as has been held by Roemer,* Shumard, White† and others.

The Washita Division.—These upper beds of the Comanche series, while a direct stratigraphic continuation of the Fredricksburg division, are probably the equivalent of the middle cretaceous beds of Europe, as shown by the remarkable identity of its fauna. Concerning this formation I have said‡ that while the uppermost strata of the Washita division have many species characteristic of the lower middle cretaceous of Europe, I believe that there is no room to doubt that the deep marine fauna of the whole of the Comanche series shows a wonderful similarity to well known forms of the European strata below the upper portions of the middle cretaceous, and bearing special resemblance, in its lower portion, to the Neocomian. The presence of middle cretaceous forms in the upper portion of the Washita division, near its emergence into the middle cretaceous land epoch, followed by the Dakota sandstones, is confirmatory of Meek's opinion that the latter could not have been older than the upper portion of the mid cretaceous. Not only is the Comanche series older, but the faunal and stratigraphic breaks between it and the upper cretaceous are complete, and show in this a great similarity to the European cretaceous. This formation is the northern termination of the lower cretaceous of Texas, Mexico and South America.

The Upper Cretaceous Series.—There can be little doubt but that the lower cretaceous epoch of subsidence was fol-

*The cretaceous strata of Texas altogether belong to the Upper Chalk, i. e., the chalk above the Gault, and indeed so much so that they correspond to the horizon of the White Chalk (Etage Senonien, D'Orbigny) and to the upper part of the Chloritic Chalk (Etage Turonien, D'Orbigny) of Europe." (Ferd. Roemer. Kreid. von Texas, p. 25.)

†It is a well known fact that we have in North America no strata, which are, according to the European standards, equivalent with the Lower Cretaceous of Europe, but that all North American strata of the cretaceous period are equivalent with those of the Upper Cretaceous of that part of the world." (Dr. C. A. White, Eleventh Ann. Rep. U. S. Geol. and Geogr. Survey for 1877, p. 264, Washington, 1879.)

‡American Journal of Science, April, 1887.

lowed by an extensive mid-cretaceous land epoch, which in turn was followed by another profound marine subsidence, as recorded in the rocks of the upper cretaceous formations. The first of these is seen in the littoral Dakota sandstones, which, as the waters deepened, were followed by the more argillaceous Colorado shales, and finally by the deep (infra-littoral) chalks.

The extent of this chalk from Rocky Comfort and from the Rio Grande northward through the Texas Pan-handle into Kansas, Colorado and Nebraska, together with its characteristic fossils, has been given. It has never been identified in the United States east of Rocky Comfort. Messrs. Meek & Hayden who studied this formation in the Nebraska Territory upon the evidence of its fossils, properly considered it as the American equivalent of the lower chalk and the upper greensand of Europe,* a resemblance which is seen, not only in its fossils, but its lithologic characters, which are identical in composition and character with the descriptions of those of the lower chalk of England, and it is very probable were simultaneously deposited in the infra-littoral depths of the same ocean, the sedimental and paleontologic characters having even more similarity than those existing in the deep waters beyond littoral influences on both sides the Atlantic to-day. The presence of this formation has not been demonstrated in the trans-Mississippi Gulf States, nor in New Jersey, but I have seen its fossils from the so-called "Tombigbee sands" of Mississippi and Alabama.

The Middle or Marly Beds of the Exogyra Costata Series, which are the direct stratigraphic continuation of this chalk formation, is the southern part of all the cretaceous beds of the Alabama region above the Tuscaloosa, and of New Jersey below the middle marl bed. The fossils of this formation common to America and Europe, show it to be closely related to the upper greensand and lower chalk, and

*United States Geological Survey of the Territories, Vol. IX: "A Report on the Invertebrate Cretaceous and Tertiary Fossils of the Upper Missouri Country." By F. B. Meek, Washington, Government Printing Office, 1876, pp. xlii-xlv.

the nature of its sediments confirm this opinion. The latest cretaceous beds of the northwest are either later or the littoral continuation of this series, probably the former.

HISTORY RECORDED IN THE NEOZOIC FORMATIONS.

The order of sedimentation and the movements of the earth's crust as revealed in these formations are probably as follows :

The littoral Trinity formation deposited against the upturned mountain rock of the older continental line is the first evidence in this region of a continental subsidence, beginning the American cretaceous, which was followed by the semi-chalky oozes of the Comanche series over a wide area, and shows that they represent a deep and long continued marine deposit. The record of the Comanche series shows the prevalence of this deep marine condition in this southwestern area and most of Spanish America, which finally ended in a continental elevation and mid-cretaceous land epoch whose eastern margin is recorded in northern Texas, Kansas and Nebraska by the plant-bearing Dakota formation (the beginning of the upper cretaceous?) and by the great Austin-New Braunfels nonconformity in southern-central Texas. (See American Journal of Science, October, 1887.)

This continental period must have been long, for the rocks of the upper cretaceous (*Exogyra costata*), which were deposited upon them, show that its continuation was sufficiently long for a complete change of all the specific and most of the generic characters of the ocean life during the intervening time. This land interval between the upper (or *Exogyra costata* series) and the lower formations (Comanche series) of the American cretaceous is one of the most apparent and well defined breaks in the whole geologic history of this continent.

The beginning of the upper cretaceous was marked by another profound subsidence, as is recorded in the *Exogyra costata* series. The oceanic waters marking the culmination of this subsidence not only deposited the chalks of Arkansas and Texas, but overspread most of the interior continental range or Rocky mountain region of the United States from

British Columbia to Mexico, and from Mexico around the Mississippi embayment to Alabama. From the great similarity of sediments in Europe, it is probable that the arms and main body of the Atlantic ocean spread at that time from Palestine in Asia to the Sierras of California. That this subsidence was profound and long continued is clearly indicated by the great thickness and homogeneity of the lower chalk beds, as found at Rocky Comfort and over the entire area, and by the succeeding marls.

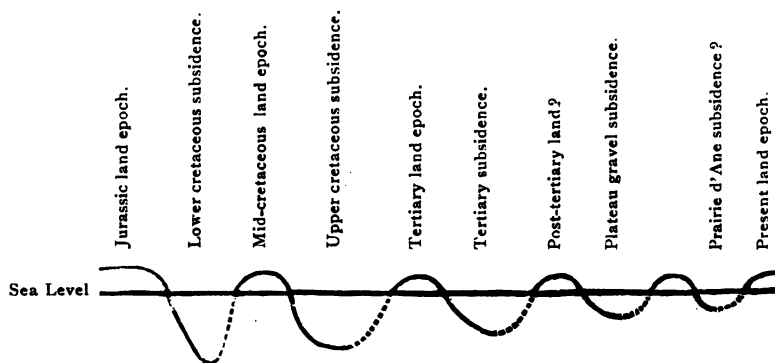
This subsidence was mostly during the first half of the upper cretaceous, for the gradual shallowing of the waters after that time from infra-littoral to sub-littoral is recorded in every part of the strata, which gradually change from the deep sea, sparse, molluscan Niobrara chalks to the impure chalks and *Exogyra ponderosa* chalk marls, and from this to the more arenaceous, and less calcareous but still foraminiferous strata composing the Washington sands of Arkansas, the so-called Ripley and rotten limestone beds of the Mississippi-Alabama region and the lower greensands of New Jersey. This closing littoral condition may have had its continuation in the deposits of the Fox Hills of the northwest.

That this shallowing continued until land conditions were ultimately reached at the close of the cretaceous is recorded in the non-conformity between the cretaceous and tertiary, and the land debris composing the Camden sediments, whose great lignitic deposits represent the forests of that continental elevation. Along the whole Atlantic slope north of the Rio Grande all remnants of this post-cretaceous land are destroyed by the eocene invasion, which eroded away, as shown in the Big Deciper non-conformity, the latest deposits of the upper cretaceous series.

The tertiary and quaternary history of the southern United States remains to be written. These formations would not be mentioned at all in this paper were it not for the purpose of clearly defining the cretaceous. It is sufficient to say that the Camden series records the beginning of a slow subsidence, initiating the tertiary period, a subsidence during which were de-

posited the sediments now forming most of the country east of the coastward cretaceous border. This subsidence, or series of subsidences, continued through tertiary times, but its history cannot at present be written. What land conditions ensued, we know not, for the evidences of those conditions were destroyed by other and still greater quaternary subsidences, which carried the waters far inland over all other outlines to the mountain region. The whole region was more than once inundated during geologic times by waters, which wore away much of the underlying formations, so that what is now revealed of them is but a fraction of their former thickness and extent, and at the same time covered them with their own debris. Since these quaternary inundations the whole Atlantic and southern coastal plain has been elevated at least 600 feet above the level at which its beds were deposited.

From the above sedimentary evidence it will be seen that there have been many movements in the earth's crust, so that any point of the region, in that infinite period of time which has elapsed since the waters along the old Trinity shore line beat against the Ouachita mountain barrier, would have risen and sunk above and beneath normal sea level at least as often as is shown upon the following diagram :



However numerous these continental oscillations may have been, their greatness, importance and bearing upon the geologic history of this region can be neither appreciated nor perceived until the continuation of these formations beyond the

Arkansas line, and the great distortions of the little known mountain area is studied, and the history of the degraded and remnantal Ouachita mountain system is developed.

That the region has been one of great weakness is the only logical deduction that can be made from its strata.

The degradation and wasting of these formations by the alternation of land and marine conditions is incalculable, especially that of the upper Comanche series, that of the lower chalk of the upper cretaceous; the upper portion of the upper cretaceous series, of the Camden series, and the whole of the quaternary inundations, not to mention the subaerial erosion during continental intervals, which must have been enormous. In fact, the existing sediments and their extent can be only a mere fraction of what these great formations once were. The planing off of twenty miles in width from the entire southern slope of this mountain system in quaternary times, as shown by Dr. Branner, in the great denudation of the central denuded region of Texas, afford but slight illustration of what the aggregate of this destruction has been.

The great erosion planes between some of these formations may also account for the absence of horizons of certain of the cretaceous which are missing here. The "Dakota sandstone" of Denison, Texas, the fish shales at the base of the lower chalk, and the great Laramie of the West have not been exposed at the surface here, however, but represent the western littoral beginning of the Arkansas series of deposits.

The relation of these formations to the paleozoic mountain barrier is also of interest. Proceeding westward along the meso-paleozoic parting, and examining contacts which have been exposed by the recent denudation, the following relation will be found to exist between the different formations and the paleozoic. North of the mouth of the De Roche on the Ouachita river, the Camden series and the other tertiary beds rest directly upon paleozoic rocks. From this point to the Little Missouri the upper cretaceous beds are seen in contact with the paleozoic. From the Little Missouri to St. Joe in Texas, southwest of Weatherford, and perhaps all around the north-

ern eastern half of the circumference of the paleozoic area there, the Trinity beds rest directly upon the carboniferous, and from thence westward they rest on the permian. Nowhere in Arkansas does the Rocky Comfort (Niobrara) chalk or the Comanche series touch paleozoic rocks, but from the entire absence of littoral evidence, except in rare instances, in their fossils and sediments, together with their dip, it is evident that they must have once have extended upon, and been limited by the southern line of the mountain region of Indian Territory, Western Arkansas and Texas, before the great upper cretaceous and post-tertiary inundations. Finally, the recent surface degradation is very great. While the cretaceous strata are so concealed in Arkansas, and their thickness so little apparent to the eye at any single exposure, it must nevertheless be evident that they aggregate many thousand feet at present, and only represent a small fraction of their original thickness and extent. Were they composed of hard, brittle and massive rocks offering lateral as well as vertical resistance, as is the case with the great sediments of synchronous age in the far west, where rivers have narrow canyons, often times 2000 feet in perpendicular depth, and had they not been ground away by the quaternary invasion, their former thickness would be proportionally as apparent and impressive. But one need only think of the average annual degradation and multiply it into the infinite period of time that these forces have been in operation to realize that the neozoic strata of Arkansas are but an infinitesimal remnant of their former greatness.

The extreme diversity of the neozoic formations, and the manner of their occurrence in the southwestern portion of Arkansas makes this one of the most interesting portions of the United States. Here, we have in place of merely the uppermost cretaceous beds, a range of formations from the oldest cretaceous, to the tertiary, covered by remnants of quaternary deposits, that throw new light, not only upon this particular region, but on the history of the continent as a whole.

Finally, by the light of these investigations in this Arkansas-Texas region, including all the region west of the Missis-

ssippi, east of the Rio Grande, and south of the Ouachita orographic system, we are enabled to present the following provisional conspectus of the post-carboniferous formations, which will serve as a basis at least for future progressive investigation and criticism.

SYNOPTICAL TABLE OF THE NEOZOIC FORM-

	Recent.	GROUP.	SERIES.	FORMATION.	TYPICAL LOCALITY.	THICK- NESS.	
							Total.
NEOZOIC.				Surface debris, alluvium, transported and residual soils, gravel, etc.			
				1. Red River Loess Phase.	Mastodon beds of upper Wichita, Brazos, Red, Colorado and interior coastal region of Texas and Red river valley of Arkansas and Indian Territory.	+100	
				2. Prairie d'Ane Phase.		+100	
				a. Prairie d'Ane white clays and hummocks.	Hope, Prescott, Bois d'Arc Prairie, New Boston Prairie of Texas, post-oak region of Roberts, in part.	+75	
				b. Ferruginous sands and jasper gravel.	Town creek and east Washington.		
				c. Basal white quartz gravel.	Washington and vicinity at cretaceous contact.		
				3. Plateau or Centre Point Gravel Phase.	Paleo Nezoic border of northern Clark, Pike, Howard and Sevier counties.	+150	
				a. Dark quartzitic stratified gravel of Centre Point.	Summit of all divides of Howard county and southern margin of plateaux.	+100	625
				b. Sevier county red land.			
				4. Camden Series.			
				a. Cleveland county red lands.	Mostly south of Fourche mountains and east of Iron Mountain railway.		
				b. Camden beds.	O. H. Marks's place, Red Land township, Cleveland county.		
				c. Little Missouri Lignites.	Bluffs at Camden.		
				d. Manchester shales.	Mouth of the Little Missouri river.		
				e. Arkadelphia shales.	Manchester Landing near the mouth of l'Eau Frais.		1000
				5. Upper Cretaceous or Exogyra Costata Series.			
				a. Washington Greensands.	Town creek valley, Washington. Upper beds of high Bluff of Ouachita, near Arkadelphia.	50	
				b. High Bluff blue sands. Big de Gray beds.	High Bluff of Ouachita, Arkadelphia, Nacotch Bluff of Little Missouri, Beirne; slope of creek valley three miles north of Washington.	125	
CRETACEOUS.			UPPER.	c. Big Deciper calcareous sands.	Bluffs of Big Deciper, six miles south of Arkadelphia. First railway cut west of Washington.	100	
				d. Marlbrook or G. vesicularis chalk marl.	Upper Roseman place, Clark county; Marlbrook-Columbus divide, Hempstead county.	150	
				e. Brownstown or E. ponderosa yellow clay marls.	Brownstown, Howard county; western Hempstead county; southeast Pike county; Okolona, etc., Clark county.	300	
				f. White Cliff chalk.	White cliffs of Little river.	150	
				g. White Cliff sub-chalk.	Base of White cliffs of Little river.	+60	
				h. Rocky Comfort Chalk.	Rocky Comfort, Little River county.	500	1335
				NOTE—The downward continuation of these beds—the Eagle Ford shales and Lower Cross Timber sands—do not crop out in Arkansas.			
				MID-CRETACEOUS LAND EPOCH, marked by a complete unconformity in this section.			
				6. Comanche Series.			
				A. Washita Division.			
				a. Cerro Gordo blue chloritic clays.	A. Indian Territory line at Little river; Cerro Gordo Post-office, and south for fifteen miles.	+250	
				b. G. pitcheri. Upper Little river limestone.			
				B. Fredricksburg Division.	B. One mile north, and three miles east of Cerro Gordo. Bed of Little river.	+60	+310
				7. Trinity Division.	Fort Towson road, from Wolf Creek Post-office to Ultima Thule. Gypsum bluffs of Little Missouri. Upper Cross Timbers of Texas, from St. Joe south to Granbury.		+250
				a. Upper crawfish sands.			
				b. Ostrea franklini beds and limestone.			
				c. Basal (lignitic sands) with vertebrates.			
Paleozoic.			LOW-ER.	8. Paleozoic.			
				"Mountain rock" of Indian Territory—Arkansas mountains.	Interior (mostly northward) of the above.		3520

ATIONS OF SOUTHWESTERN ARKANSAS.

RELATION TO OTHER AREAS.	CHARACTER OF SEDIMENTS	CHARACTERIZ- ING FOSSILS
Post-glacial ("Champlain?") epoch of older classification extending far west through the Indian Territory.	Ferruginous, arenaceous and calcareous debris; white below and orange colored above. Sands with mixture of clays.	<i>Mastodon giganteus</i> . None seen by writer. <i>Helix. Pupa.</i>
2. "Orange sand?" of Miss. Hummock or second bottom formation in part of Miss. Red sands of northeast Texas. Hummocks of same. Probably related to upper terrace of Terra Blanca phase of Canadian, Pecos and Rio Grande rivers, and connected in origin with the Grand Prairie erosion of Texas.	Various clay sands, etc., horizontally mixed with jasper gravel, and usually without lime. Varies much in places.	Silicified wood but no special criteria found.
3. Allied by position to older Llano Estacado formation, and Burtahatchie gravel of Alabama, but no lithologic resemblance to either.	Deeply ferruginous sands, clays and gravel.	None.
a. Claiborne beds of Alabama and Mississippi. b, c, d, e. Belongs with strata called northern Lignitic in Mississippi and Alabama, which have been subdivided by Johnson and Smith, but no attempt is here made at correlations of their divisions.	Rich ferruginous and calcareous marls. Some greensand. Mostly micaceous sands and pipe clays, in varying proportions; distinctly banded; few fossils and little lime Lignite.	a. Vegetal remains at base, but as yet undefined. <i>Calyptrophorus trinodosaria</i> , <i>Cardita planicosta</i> , Lmck.
a. Lower marls of New Jersey, Lower Ripley of Mississippi. Eagle Pass beds of Texas. b. Resemble phases of Ripley, rotten limestone and upper Tombigbee horizons of Mississippi and Navarro beds of Texas.	Unconsolidated arenaceous beds with specks of glauconite; many fossils. Unlaminated sands like above but not so rich in greensand. Increased quantities of chalky lime. c. Clays and lime marls, rich in organic remains.	Casts of <i>Grassatella</i> , etc., at base. <i>Exogyra costata costata</i> var. <i>G. vesicularis</i> , <i>Ostrea larva</i> , <i>Inoceramus crispus</i> var. <i>barabini</i> , <i>Bromasaurus</i> of Leidy.
<i>Exogyra ponderosa</i> marls of Texas, with some exceptions, as described by Roemer. Probably destroyed in most places, but included in above in Texas. * * * * * Austin limestone [chalk] (in part) of Roemer; Dallas limestone [chalk] of Hill; Niobrara beds (in part) of Meek and Hayden.	Same as above with increased proportions of carbonate of lime. Pure white chalk. Pure white chalk with siliceous and glauconitic grains. * * * * * Impure chalk.	<i>Exogyra costata</i> var. <i>ponderosa</i> . <i>Textularia</i> and other foraminifera. * * * * * <i>Inoceramus biformis</i> , <i>Nautilus</i> sp. ind., <i>Radiolites austriensis</i> , Roem.
6. Incomplete representation in Ark. of Texas Turonian Neocomian, and cap rock of Tucumcari mesas alleged by Hall and others to be the equivalent of this section (the base of No. 5.)	6. Clays and impure limestone (metamorphosed shales), stratified at top and more massive at base.	A. <i>G. pitcheri</i> vars. <i>navia</i> and <i>forniculata</i> , <i>Macraster elegans</i> , Shum. <i>G. sinuata</i> . B. <i>Am. pederalis</i> , <i>O. flabellata</i> , <i>G. pitcheri</i> , type var.
a. Upper Dinosaur sands of Texas and probably sub-stratum of Tucumcari mesa. b. Lower beds of Dinosaur sands of Hill in Texas, and probable uppermost continuation of Marcon's Jurassic of Pyramid Mount.	Pure white sand as seen at Weatherford and Decatur, Texas. Lemon yellow sands of Messer's creek valley, with alternations of lime bands; rich in fossils, both molluscan, vegetal and vertebrate.	<i>Pleurocera strimbs-formis</i> . <i>Ostrea franklini</i> . Dinosaurian remains.

Solid lines indicate complete faunal and sedimentary non-conformity. Stars indicate that contact was not seen, but formations supposedly conformable. Dotted line indicates continuity between over and underlying beds.

PART II.

CHAPTER XVII.

ECONOMIC GEOLOGY.

INTRODUCTION.

In this age of specialization the duties of the geologist practically end when he has delineated the structure of the earth's crust and the changes through which it has passed. The facts which he thus obtains are given to specialists in other lines of work to be used in the applied sciences, such as engineering, agriculture, architecture, commerce, etc., and he who geologizes well has little time to spare or energy to diffuse in other specialties. But the geologist who builds up a structure of fact must remember that distinct classes call upon him for two distinct statements of the same fact. His fellow specialists demand that these statements be in scientific language, while those who follow other specialties demand that each point be clothed in popular language, and that special attention be called to the utility of every fact discovered.

The possible application of the results described in this paper are very numerous, but the writer has not the time for extending these subjects to their fullest, and will set forth only such facts as have immediate and direct bearing upon the material interests of the people, and which will enable them to obtain from the structure or geology of the earth greater returns than it now yields.

Since the conditions of the region are preponderatingly agricultural it is but proper that agricultural interests should receive most attention, especially since agriculture is, of all applied sciences, the one most intimately related to geology.

Agriculture is the art of inducing and increasing the growths of plants required by man. All cultivated plants had their origin in the wilderness, and have reached their present perfection by means of human study and experiment. Agriculture is not the gathering of wild fruits, timber and other native vegetal products, but rather the resetting, cultivation, grafting, tillage, and other study and assistance to plant growth. Plant growth, wild or cultivated, is dependent upon the chemical ingredients and physical structure of the soil and upon climatic conditions. Soils owe their origin to the rocks of the earth's substructure, which are modified and changed by natural agencies, and the ultimate diversity of vegetation, such as exists between the different regions of Arkansas, is primarily due to the chemical and mechanical conditions of the fundamental stratigraphy. Hence, under favorable climatic conditions, the ultimate principles which underlie all agriculture can be understood only by a study of the rocks from which the soils are derived, their structure, composition and extent. This study once made, the after knowledge of methods for utilizing the conditions is but a question of application, and may be more economically acquired and administered. This is the relation of geology to agriculture:

Geology is especially concerned with the origin of soils, and hence much of this part of the report is devoted to this subject, including the geologic classification of soils and their amelioration by direct geologic agencies.

For those portions of the work which pertain rather to pure agriculture than to geology proper the writer has drawn upon agricultural authorities, and especially from the valuable agricultural text-book of Prof. John Wrightson of the Agricultural College of Cirencester, England.

In a recent pamphlet entitled "The French Viticultural Mission" to the United States, published by the Texas Geological and Scientific Association of Houston, Texas, the writer has already pointed out the important fact that the calcareous soils of southwest Arkansas and of Texas are more closely allied to those of England and France, than to the rest of the

United States, and that we must turn to the accumulated experience of those countries for instruction rather than to the colleges and experimental farms of the eastern United States.

The value of the calcareous marls for the non-calcareous soils of Arkansas, and their convenient commercial juxtaposition should be worth millions of dollars to the present and future agricultural populations of the state, for by use of these the healthful uplands of the state can be made profitably habitable.

Agricultural interests, although the most important, are by no means the only natural sources of value in this region, and in the latter part of the report attention is called to many important facts concerning drainage, house and road building material, forests, salt, gypsum and other useful substances.

The details of the stratigraphic and surface geology of the region have been given at length in the first part of the report, chiefly for the purpose of making clear the agricultural and other economic conditions of the region which may be useful to man. The foundation of all these is, undoubtedly, found in the ancient sediments of the substructure just described. There can be no strict division of the economic products of the region into organic and inorganic, for too many of the apparently inorganic substances such as pyrites, lignites and shell marls, are combinations produced by organic action, and hence for convenience the economic conditions of the region will be discussed independently of such divisions.

CHAPTER XVIII.

THE ORIGIN OF SOILS.

The soils are by far the most important economic product of the geologic strata of the region, and it is upon the study, preservation and improvement of these that the region's future prosperity is dependent. Their origin and distribution have been intimated in previous pages, but no attempt at classification has been made.

The substructure as shown was once composed of sediments, mostly marine, deposited in the ocean's bottom. The present contours and other conditions of the surface were gradually formed by exposure of these to the weathering effects of the atmosphere.

These effects were not produced, with some exceptions, in the area under discussion, by violent upheavals, "cataclysms," volcanic disturbances, glacial action, as has been popularly supposed, but by forms whose workings may be seen in operation at the present day, such as the power of water to hold in solution and to transport solid matter, of the gases of the air to combine with and deposit the mineral ingredients of the rocks, the effect of cold and heat, the penetration of roots, producing mechanical disintegration, and the tillage and other work of man.

These agencies are disintegrative in their action upon the original sediments; the resulting debris may either remain in place as a surface debris or residual soil of the underlying formation, or may be transported by waters and winds, in various degrees of coarseness, and redeposited over other areas and formations.

The quantity and manner of rainfall and the resulting conditions of overflow have an important bearing upon the surface of a country and upon the composition of its soils. In southwestern Arkansas rains occur in spring and winter, while

during the dry weather of autumn the surface soil becomes loose and friable, and is readily washed away. This process is repeated until the productive stratum is either worn away or preserved and kept from transportation by the protection afforded by the forests or other plant growth.

By the river system the surface debris is collected and re-distributed over bottoms or ultimately carried to the sea, where it constitutes the sediments of new formations. The flood plains of the streams, as can be seen upon any map, vary in width as they pass through different formations. Their present beds and divides change with every rainfall. There is a common but exaggerated saying that the portion of Red river in Arkansas never flows in the same channel two years in succession. In a journey down the Ouachita hundreds of old sand and gravel bars are visible which are cut through by the present channel at right angles to the direction of the stream when they were originally deposited. Instances of the annual washing away of farms into rivers are numerous. The annual meanderings of these streams are less in the cretaceous area than in the tertiary, and almost imperceptible in the region of paleozoic rocks. The effect of these wide meanderings is to deposit alluvium over the bottoms on one side, and to tear away and transport material of the low bluffs from the other.

The action of the atmosphere in modifying the surface is familiar to every one. Although there is, in this region, even a superabundance of rainfall for agricultural purposes, there are short periods of dry weather, during which the surface soils become unconsolidated or friable. The heavy and often times sudden rainfalls usually remove all this loose material with great rapidity. This action is especially visible where the protective natural vegetation has been removed for the purposes of cultivation, as in the washes of the cotton fields, which fact, in itself, is a plea for the cultivation of grass crops with matted protective roots.

Rainfalls not only modify the agricultural conditions of the surface rock or soils, by their transporting power, but also in their solvent and fertilizing capacities.

The soft marls, sands, etc., of this region sometimes facilitate this action, and sometimes resist it, but in all cases the structural character of the sub-strata for many feet beneath the surface is destroyed, although the exterior does not reveal the fact until the sub-strata are artificially exposed by digging. Expansion and contraction, which are the result of changes in temperature, owing to the softness and uncemented character of the strata, have much effect here also, but not so much as in other regions where greater extremes of climate and more massive rocks prevail.

Vegetation, also, produces great changes in the surface. Forest growth, while destructive of geologic structure, is protective of soils. Wherever the sub-strata are penetrated by the roots of trees they are loosened, and atmospheric and aqueous action, which destroy the structural character, are facilitated. On the other hand, the dense forest growth of southwestern Arkansas has preserved great areas from destructive denudation. Deposits of leaves and other vegetable rubbish are, also, protective as well as nutritious, serving the purpose which is accomplished in more northern regions by the matted tuft which is here missing. The chemical decomposition of leaves and fallen timber plays an important part in organic changes, producing agricultural soil.

All of the foregoing alterations are accompanied by more or less chemical change, whereby the mineral ingredients of the strata decompose and recombine with the elements of the atmosphere, water and vegetation and with one another. The most conspicuous surface feature of the entire region is the radical change in color which the substructure undergoes upon exposure to these agencies. In general, the arenaceous strata turn yellow or red, and ultimately white from lixiviation; and the calcareous strata (usually of a bluish tint from contained moisture) turn white upon drying, and upon contact with organic matter yellow, and finally deep black. Sometimes, when greensand, which is a silicate of iron and potash, is plentiful, these calcareous strata turn red, as in the vicinity of Washington and at Okolona. The black surface soil, except-

ing, perhaps, that of the small igneous area near Murfreesboro, is caused by the action of lime upon organic matter; the iron is disseminated throughout the fundamental strata as oxides, pyrites (iron sulphide), greensand (silicate of iron and potash), and in other forms. The two last mentioned, especially the greensand, occur throughout the upper cretaceous beds in greater or less quantities, while the pyrites occurs chiefly in the Trinity and Camden series.

This oxidation of iron upon exposure to air and moisture is the most general and obvious chemical change in this region. To iron and its combinations are due most of the yellow orange, blood-red, green, and bluish-green tints of the soil. The ferruginated waters of the quaternary denudations may also have been instrumental in producing these red colors in the gravel plateau. Oxidation and its effects is the most marked and impressive feature of the whole region under discussion, and can be seen in progress nearly everywhere. By it the green oxide in the bluish Arkadelphia clay and shales is converted into the blood red color so characteristic of the red clay lands. In certain horizons of the Camden series pyritiferous nodules may be seen oxidizing, and thereby coloring the adjacent strata. The High Bluff sands and *Exogyra* lime marls are changed to deep orange by the oxidation of the small particles of iron it contains in combination with potash (glauconite). This process can be seen in the streets of Washington and north of Arkadelphia. It begins by the appearance of blood red blotches on fresh exposures, which soon spread throughout the mass. Both the Trinity and the Camden series show the oxidation of pyrites. The micaceous sandy shales of the latter, as has been stated, soon change to delicate pink or yellow tints, and to the dirty, reddish yellow that is characteristic of the tertiary (?) in pine lands. Wherever there is a lagoon, "cut-off," or pool in river or creek beds, iron may be seen in solution, and in process of precipitation, and cementing the gravel banks into conglomerate, and the exposed arenaceous strata into "iron-stones." Often the very recent rock masses made in this manner have an ancient

look, but I have not seen an outcrop of this ferruginous conglomerate or sandstone, that bore evidence by its position of other than the most superficial origin. The banks of "Deciper lake," a pool formed by the local enlargement of Deciper creek, which stagnates and diminishes by concentration in summer, are lined with huge conglomerate boulders of this origin.

CHAPTER XIX.

THE CLASSIFICATION OF SOILS.

The lands of the region under discussion are popularly and erroneously classified by their color and texture instead of their chemical composition and derivation. They are usually termed "black" and "red," "sandy" or "clay" uplands or lowlands, which have little definiteness, for the following reasons: The color of any soil is not generally fundamental, but is usually dependent upon the conditions of its exposure to atmospheric agencies. For instance, black color of soils is generally due to vegetable decomposition, but the qualities of the soil that produce this decomposition are very variable. It may be due to an excess of moisture or of some chemical ingredient, like lime, iron, etc., or it may be from the decomposition under normal surface conditions. There is an infinite number of so-called black lands in this region. The derived soils of many of the creek and river flood plains, where vegetable humus has long been in the process of operation, are called "black lands." In Clark county the term is applied to both the residual soils of the Manchester shales, of the region known as the "rich woods," and also to the "Okolona black lands," another residuary soil, but with entirely different chemical and structural characters, while both these are quite different from the black lands of the Trinity formation in Pike and Howard counties. The black lands above the igneous area of Pike county are also of entirely different origin and properties. The term red land is equally confusing. Red colors may be seen where a road or railway cut has exposed the strata to the atmosphere and sunlight, but the same strata two feet distant where protecting vegetation is at hand, may be of an entirely different color. Then there is another character of red soils which is not necessarily the result of superficial oxidation, but may have been the fundamental color of the strata

from which the soil is derived, as is seen in the great red beds of the Llano Estacado, from which the sediment of the Canadian, Red, Brazos and Colorado rivers are mostly derived.

The surface debris resulting from the disintegration of rocks, whether tillable or not, is geologically known as soil. Soils are classified by their relation to the rock from which they are derived, as—

First—Residuary, or endogenous soil, or that which is the superficial debris of the more ancient formation immediately underlying it.

Second—Transported, or exogenous soil, or that which has been transported from the place or places of its residuary origin, and which is at present a redeposit upon other formations.

The residual soils are generally either exceedingly rich, or deficient in some particular chemical ingredient, owing to the method by which they were formed by the sorting and distributing powers of oceanic waters. Thus it is that the comparatively near shore Trinity formation is predominantly sandy and mixed with gypsum and the lime of littoral shells; that the brackish or estuarine Camden series, composed of alternating sands and clays mixed with the vegetation (lignite) of marshy adjacent shores is sterile; and that the deep sea sediments of greensand and chalk of the upper cretaceous series formed beyond the reach of littoral influences, are exceedingly calcareous.

Transported soils, upon the other hand, are usually more homogenous in their composition, owing to the variety of formations from which they are derived.

THE DISTRIBUTION OF SOILS.*

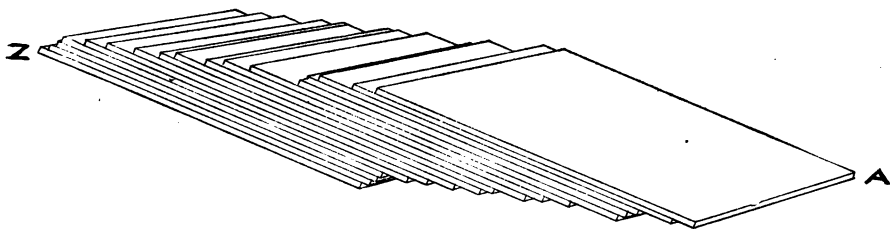
It will greatly assist the reader to grasp the plan of soil distribution if he keeps in mind the order of succession of the main beds or formations which constitute the explored crust of the earth, so far at least as Arkansas is concerned. The

*This part of the report is adapted from the Agricultural Text Book of John Wrightson, pp. 20, 22.

various strata which constitute Arkansas are superimposed upon each other in definite order.

The importance of this fact to the agriculturist is at once apparent, when we find that each stratum in turn occupies the surface of the country. It is the constant order of succession which makes the arrangement of the various formations of practical use to the agriculturist.

The arrangement of the formations may be illustrated by a very simple device. A pack of cards may be used to represent the strata. When properly placed on the table, the top-most card may be supposed to represent the newest geological formation. The card immediately beneath it will represent the stratum which underlies it. Each card in succession may be considered to represent an older rock, until we come to the bottom card, which may represent one of the primary or paleozoic groups. Place the pack in a northwest and south-east direction, and then slide it in the latter direction as in figure 1, so as to discover the upper surfaces of a large



number of cards, and a very correct idea of the manner in which the various geologic formations occupy the surface of southwest Arkansas is then obtained. A is the top card of the pack, and Z is the bottom card, and yet both are visible. If the hand is passed from A to Z along the extended pack, it must in turn traverse the exposed surface of each card until it arrives at the bottom one. Further, if, instead of looking from above down upon the pack, we look at the side elevation, it will be seen that the cards are no longer horizontal, but slightly tilted from northwest to southeast; in other words, they dip to the southeast. The position of the cards may be used to illustrate the succession of various kinds of soils in

the region under discussion. Any one who travels across this region in a northwesterly direction will pass over the various strata forming the surface in a very similar manner. All these strata dip toward the southeast, and all crop out towards the northwest. The succession and outcrop of the various strata are shown in the section of the country from Hope to Centre Point.

The newer formations are on the southeast, and the older formations successively occupy the country until we arrive at the paleozoic sandstones and shales of northern Clark, Pike, Howard and Sevier counties. This, then, is the key to the succession of the various kinds of soils in Arkansas. The student who wishes to pursue the subject further, is referred to the geologic map, and with its assistance he can trace out the various formations, as they come to the surface usually in a line from northeast to southwest.

The synoptical table on pages 188-9, and the chemical analyses, given on another page, of the principal rocks from which our soils have been derived, may be useful. Opposite each analysis will be found a few remarks as to the general character of the agriculture, and of the land.

Reference to the table will show that some geologic formations yield soils of high average fertility, while others yield inferior soils. Some are stiff and difficult to work, while others are generally free working. It must, however, be remembered that geologic knowledge, although useful, is not entirely to be relied upon. On all formations, good, bad and indifferent soils are no doubt to be met with. The mingling of formations together at their edges, the accumulation of drifted matter, the occurrence of less important strata, unnoticed perhaps in the geologic chart, and other reasons, create numerous exceptions to any rule which may be laid down with respect to the soils of a certain geologic formation.

CHAPTER XX.

THE TRANSPORTED, OR EXOGENEOUS SOILS OF SOUTHWEST ARKANSAS.

A large proportion of the soils of the region under discussion, especially if we include the Prairie d'Ane and plateau gravel formations, are exogeneous or transported soils.

As can be seen upon the map, probably one-half of the lands of the whole area are composed of transported soils.

The alluvial soils deposited by flowing waters are of great variety, both in composition and fertility, since their qualities are dependent upon the character of the strata of the country drained by the streams which deposit them and the carrying and distributing effects of the water. There is also quite a perceptible difference in many places between the character of the land of the annual and the intermittent flood plains, the former being usually much richer, and constantly fertilized by additional depositions of sediments.

All the soils of the first bottoms, or annual flood plain, and most of the intermittent flood plains of the little Missouri, the Ouachita, Terre Noir, the Decipers, or other streams, are derived from the destructive denudation of regions drained by these streams, and the redeposition of their sediments as alluvium. Since their alluviums have been depositing they have, in most cases, been changed in character by having been covered by other alluvial soils, and by the growth and decay of vegetable matter; from other causes, too, they have great local variation, and are, perhaps, most difficult to treat specifically, for their structural and chemical characters depend upon the rate of current, height of the rivers; and the nature of the formations which they drain. Nothing less than an extensive study greater than the time allotted for the whole country would be sufficient to furnish specific data for their discussion. There are, however, some general characteristics

of the different systems: these are differences between soils of individual streams; differences between the first bottoms, which are refreshed, sometimes injured, by annual overflows, and those bottoms which are only occasionally modified by freshets, and which have also been much altered by long exposure to the atmosphere. It must be remembered that one week under water annually may be equal to many years of rainfall in solvent and other modifying effects upon the chemical conditions of a soil.

I have shown in the beginning of this paper how the Ouachita differs geographically from the Red and Arkansas rivers, as to origin and the geologic character of the country drained by them. A corresponding difference in the characters of their flood plains, or bottom soils, also exists, so that the virtues and defects of one do not necessarily belong to the other.

The nature and composition of these derivative soils is but a repetition of the chemical composition of the rocks from which they are derived. This difference in the character of the alluvial soils deposited by different streams is illustrated by two widely different types of transported soils* in Clark county, to wit:

The first class of alluvial soils are those which are the debris of several formations. The transported soils of the Ouachita bottoms within the cretaceous area above the mouth of the Little Missouri, do not come from the rich cretaceous strata themselves, but are mostly composed of the sterile clays derived from the paleozoic area above, and hence are not so rich as the bottom lands further down the river between the more sterile uplands. The former lands are by no means useless and incapable of improvement, however.

The flood plain of the Little Missouri, on the contrary, is composed of the debris of every formation described, except

*The derivative soils of river flood plains are seldom, if ever, derived from the strata of their including highlands, but always come from some distance up the stream. For instance, any rainfall in Clark county sufficient to cause a perceptible rise in the Ouachita, would be apt to convey the sediments derived from the immediate neighborhood some distance down stream, beyond the county limits, before their redeposition.

the Camden series. It drains the rich lime, greensand, and calcareous gypsiferous marls of the *Exogyra* series and the Trinity beds, which with judicious mixture with clays of the paleozoic area and vegetal humus, produce a remarkably fertile soil. The same can be said of the West Saline, the Cossatot, and both the Mountain and Rolling forks of Little river, with the exception that the last two do not pass through the upper cretaceous series to any great extent.

The transported soils composing the bottoms of Red river, are exceptional, and do not properly belong to the category of the above rivers, as has been shown in the remarks upon hydrography, but are rather to be classified with those of the Brazos and Colorado rivers of Texas. The bottom lands of these rivers are of a rich red color, which is the color of the strata from which they are derived in western Texas. These red colored alluvial lands of the Red river are noted for their wonderful fertility, and constitute by far the best land of Texas, Louisiana, and of the southwestern corner of Arkansas. The source of their fertility lies in the gypsum and the homogeneity of their material, together with the other ingredients of the Red river loess phase.* These red soils are a conspicuous feature of the Red river flood plains, both past and recent, from its mouth to its head in the Llano Estacado. They are the only soils in Arkansas that are not the result of surface oxidation, except, perhaps, those of the "red" rises of the Arkansas, the Canadian branch of which has its source in the same red beds as the Red river.

Another kind of transported alluvial soil is that of streams which have their entire courses through one kind of rock. A good example of this is found in the valleys of the Terre Noir, Bradshaw, Deciper, etc., in Clark county, and the Ozan, in Hempstead. Here the alluvium is directly traceable to the strata of the adjacent uplands, and generally combines the good qualities of all of them, and ameliorates such bad

*The discussion of the ingredients of these soils, and their general agricultural characters is deferred to p. 207 *et seq.*, where analyses are given, and suggestions for their improvement are found.

qualities as may be due to an excess of a single ingredient. The last mentioned streams, most of which have their courses through the upper cretaceous series, the individual horizons of which are characterized by the preponderance of certain ingredients, such as lime in one, greensand in another, or sterile sands in another, are mostly characterized by rich black, loamy bottom lands, wherein these individual qualities have been amalgamated into one forming a good general soil. The black, sandy calcareous loam of Major Jesse Ross's place, at the intersection of the Terre Noir and Bradshaw's creek, is a good example of alluvial land of this character.

Still another and frequent kind of transported soil is that which is the washings from an adjacent formation, transported from a neighboring eminence to a plain below. This process certainly enriches the soil, as is illustrated in all the black land bottoms, like those of Major Coulter's plantation, section 24, 10 S., 29 W., in Sevier county, in the valley border of the Ozan in Hempstead, and of the Big Deciper in Clark county, where the residuary soils, or surface weatherings of the *Exogyra ponderosa* marls are carried down by each rainfall upon the benches of the creek valleys. Although the origin of the soil is the same as the cultivated residual soils of the adjacent highlands, its fertility is nearly doubled, the process of removal having performed on a grander scale, exactly what the agriculturist usually accomplishes artificially, by plowing and applying humus, to-wit: exposed the mineral element of the strata to more thorough atmospheric decomposition, thereby converting the insolubles into solubles, and gathering vegetable matter, such as decaying fallen wood and leaves, etc., which neutralizes the excess of lime and adds to the fertility of the soil. The mechanical properties of the soil are also improved by this process.

CHAPTER XXI.

THE RESIDUAL SOILS OF SOUTHWESTERN ARKANSAS.

Nine-tenths of the surface soils of the region are the direct surface outcrops of the fundamental marine strata, and constitute a most important feature of the geology—perhaps the most important—for by the study of these we arrive at the secret of the fertility of the soils, upon which the agricultural and other economic possibilities of the region depend. As has been shown in the chapter on the fundamental stratigraphy, the chief characteristic of the marine sediments which form the strata is their unconsolidated structure, whereby they readily yield to disintegration on exposure to atmospheric agencies. I have also shown that the color and structure of these strata radically change upon exposure for a short time. These changes tend to make the surface appearances homogeneous, since nearly all the formations possess the oxidizing iron in some shape or other, so that it is not only exceedingly difficult, but sometimes impossible, to differentiate them by their surface appearances. The surface is constantly disintegrating, and as the debris thus formed unites with decayed organic matter, agricultural soils are formed. The disintegration in humid forest-covered portions of Arkansas, although great in amount, is not so apparent as in the arid regions to the west in Texas and Indian Territory, because here the debris of the forest growth covers the immediate surface, concealing from the eye the melting away that is going on beneath. But wherever man has cleared the native forest, this dissolution of the strata becomes only too apparent, as can be seen in the washing away of the farms, the constantly deepening gullies of roadsides, and railroad cuts.

The Prairie d'Ane Soils.—The Prairie d'Ane soils, especially those of the prairies and post-oak regions, seem to possess many features desirable for scientific agriculture, such as

a clay matrix for retention of fertilizers, and good drainage, but they are apparently deficient in some materials, probably lime and potash, as is indicated by the natural flora. These soils exhibit many points of identity with the extensive prairies of eastern Arkansas, which, like them, are conspicuous for the absence of some simple mineral ingredient which can easily be supplied from the extensive marl beds described in this volume. By this process these soils, now comparatively worthless, might readily be converted from the apparent waste they now are in to some of the most profitable lands in the State of Arkansas.

The Soils of the Post-tertiary Gravel and Red Lands.—The gravel and red land soils are coextensive with the gravel formation given on the general map. Both the basal till and the gravel (which is imbedded in a clay matrix) constitute some of the most valuable soils in Arkansas. While not so rich in fertile ingredients as other soils the gravel, clay and sand constitute a mechanical matrix that is excellently adapted for holding fertilizers, which gives them an advantage over most other soils.

These lands are remarkably well adapted to "all round" farming, especially to the cultivation of fruit. They are not, however, good cotton lands, and the manner in which they are almost solely devoted to that comparatively unprofitable plant is a travesty of the gifts of nature.

The lands, as will be seen by the analyses, are especially lacking in lime, a defect for which nature has provided a convenient and accessible remedy in the lime marls of the adjacent upper cretaceous series. Surrounded as they are by unlimited beds of gypsum, greensand, and lime marls, providing every desirable ingredient, it is doubtful if any lands in the world are so conveniently located to natural fertilizers as the great red land plateau of this region. It is a remarkable fact that the use of these fertilizers is utterly unknown to the present farmers. Even stable manure is not utilized, and farms which could be made the best, are often exhausted and abandoned.

The Soils of the Camden Series.—The strata of the terranes of the Camden series are very sandy, lose their structural character on exposure and become a fine grained pulverulent sand, and, of all soils, are the most difficult to place stratigraphically by superficial appearances. Most of the soils of the Camden series are of this class. There are some broad exceptions to this rule, however, notably in the Cleveland county red lands and the L'Eau Frais shales.

They are all of a reddish color, usually of a lighter orange tinge than the deep red of the plateau gravel soils or the stratigraphically lower residual soils of the upper cretaceous series.

The micaceous, laminated clays and sands of the main body of this series constitute the basal formation of nearly all the so-called oak and pine flat upland, sandy and clay lands east of the Iron Mountain railway and as seen at Camden, Fordyce, and other places. The alternating white sands and blue clays of this series disintegrate and oxidize, especially on the penetration of superficial water. The laminated structure disappears upon exposure, and the iron contained therein changes the color from drab, blue, olive, etc., to reddish yellow. This can be seen nearly anywhere, but a typical illustration is shown in the cut of the St. Louis, Arkansas and Texas railway, a hundred yards south of the station at Camden. Here the transition from thin alternating strata of white clays and sands into the red, sandy clay surface soil is complete. This transition may be seen in all the bluffs of Ouachita county.

Some analyses of characteristic residual soils of these average lands of the medial Camden series, including the Cleveland red lands, L'Eau Frais shales, and Arkadelphia shales, are given in the table of analyses elsewhere.

The phenomenal red lands of Cleveland county are the residua of the formations which have been taken as the top of the geologic section in this paper, and which are probably the Claiborne stage of the Eocene tertiary. These lands are named from the red color imparted to them by the oxidation

of the glauconite, and their fertility is derived from the calcium carbonate, which is still insufficient, of the shells of the contained fossils, and from the greensand which may be the source of the iron and potash.

The process of the change from substructure to surface soil in the red lands is as follows: The substructure, which is composed of a calcareous laminated shell marl, is usually greenish blue or lemon yellow in color. Upon the infiltration of moisture the calcium carbonate of the shells is dissolved and the sesquioxide of iron deposited throughout the arenaceous mass, producing the great concretions of fossiliferous iron ore that are characteristic of these lands, wherever they occur from Texas to Mississippi. The phosphoric acid comes from the organic substances originally secreted by the mollusks.

Another characteristic residuum of the Camden series, though not entirely peculiar to it, is the alteration, in the arenaceous strata of the lignitiferous and pyritiferous layers of the sands into iron-stone (locally called "iron ore") and hard siliceous rock.* This is due to the porous structural character of certain layers, free percolation of waters which become heavily charged with iron or silica from some of them and re-deposit them in others, thereby cementing the sands into firmer rock. Especially is this true where water stands for a long time on these lands.

The heavy clay shales or L'Eau Frais beds of the Camden series I am inclined to believe, weather into the "rich woods" soils of Clark county. These constitute a long strip of black lands along the Iron Mountain railway, mostly east of it, from Curtis to Gum Springs. The soil is very black and sticky when wet, and is sixty or seventy feet deep. It is richly timbered with the best hardwoods, such as hickory, ash, walnut, and many kinds of oak, especially white oak. Concerning the

*Corollary to this fact, there are numerous mineral springs throughout the exposures of these formations which are heavily impregnated with iron and silica, thereby rendering them not altogether the best drinking water, the absence of which is the most serious deficiency in the region.

geologic origin of this soil, there are two theories, however. The first, as expressed by Owen, is that it represents the sediments of an ancient lake (resulting from a river cut-off), as is now seen in Big Deciper lake. The second theory, of my own, although I do not feel entirely satisfied of its correctness, is, as stated before, that the black lands of these rich woods are the residua of the L'Eau Frais shales, as seen at the mouth of that creek and Manchester landing. They are obscured by river alluvium between the thick woods and those places. The uniform thickness of the black dirt both at Curtis and Gurdon, which are similar, as shown by sections of the artesian well borings of those places, the direction of the normal dip of the region, and the similarity in composition, are the facts upon which this theory is based. The following section at Sloan's place, section 8, 8 S., 19 W., is typical of the region:

PROBABLE HORIZON.	SECTION NO. 7, SLOAN'S GIN HOUSE, SOUTH OF GUM SPRINGS.
L'Eau Frais and Arkadelphia shales.....	{ Yellow, unfossiliferous joint clays, and iron-stone, seen on high places in railway cuts, etc..... 20 feet.
	{ Black clay soil, constituting rich woods (This with rest of section from well boring)..... 64 feet.
	{ Clear or orange tinted sands..... 2 feet
	{ Blue clay 1 foot.
High Bluff Formation ?.....	{ Bed rock pulverized by well augur 1 to 3 feet.
	{ Sands with water (Cretaceous?).....

The wells at Gurdon pass through a similar section.

The chemical composition of the rich woods black land soils from the Buckner place in section 19, 8 S., 19 W., is given in the table.

The residual soils of the Arkadelphia shales, which are treated as the base of the Camden series in Clark county, are difficult to describe. These soils are readily detected when the shales form the top of a ridge, the basal slopes of which are of the underlying cretaceous, but otherwise it is difficult, owing to the varying proportions of sand and clay they contain. In fact after studying them for weeks, it was impossible to identify them definitely, except where they could be found in fresh exposures in some convenient ravine or newly dug

well. They weather into either deep red clays or light white sands. The alternating bands of clays and sands oxidize rapidly, soon losing their structure, and changing from blue when moist to orange or deep red when dry, and if the stratum is preponderatingly sandy, it is impossible to distinguish residual soils from those of the overlying or underlying formations. When dry the residual soils have a dirty yellow color, but when wet and sticky they become intensely red through oxidation. The oxidation and disintegration of these shales is often visible, the transition being unmistakable. These derivative soils have occupied a prominent part in the agriculture of Clark county.

Bordering the rich woods on the west, and extending from Arkadelphia to Rome, except where interrupted by river bottoms, is a great strip of sandy lands. The eastern half of this is composed of fine residuary sand in the upper two feet, but below that point are oxidized red soils. At other places these sandy lands apparently have no sub-soil. From these facts, especially, when we remember that the structural and stratigraphic characters of loosely segregated sands are unstable, and from the close resemblance of the Arkadelphia shales and underlying High Bluff series, it is very difficult to locate minutely their geologic horizon. The eastern half of these sands, however, is, by inference, the weathered arenaceous layers of the Arkadelphia shales and that of the western margin of the High Bluff formation. These soils are heavily timbered for uplands, pine and hardwoods flourishing upon them. The timber growth, however, is an indication of the fundamental strata rather than of the tillable surface soil, and of mechanical structure, rather than of fertilizing qualities. Many farms based on these sands which were once profitably cultivated are now deserted. Their cultivation may have been due not so much to their intrinsic value, however, as to the fact that they were above overflow and more easily cleared—points which in primitive agriculture often counterbalance the superior richness of unhealthful bottom lands.

The residual soils can be seen on the slopes of all the principal ridges between Arkadelphia and Dobyville, on the Okolona road. Nearly all the farmers who cultivate the rich bottom lands have their residences upon these high red land ridges.

The Soils of the Upper Cretaceous Series.—From the extremes of calcareous and arenaceous strata of the upper cretaceous series it is evident that no generic surface appearances can be given to it as a whole. The strata are generally unconsolidated and yielding, yet in exceptional localities they are just the opposite. The structural and lithologic features are not confined to definite or extensive horizons. What may be a stratum of loose sands at one place, as at the High Bluff of the Ouachita, near Arkadelphia, by the percolation of calcareous waters from above, may become a loosely cemented calcareous sand rock a few miles distant. The following, however, are the most characteristic surface features of the principal subdivisions:

The Soils of the High Bluff or Washington Sands.—There is no demarkation between these and the sands of the overlying Camden series. In general they are coarser grained, more extensive, and in thicker beds which are measurable in feet, instead of inches, as with the sands of the Arkadelphia shales. The little clay they contain seems to be thoroughly homogeneous with the sands, instead of occurring in separate alternate laminæ. The iron, on the contrary, is disseminated through these sands in minute black specks of greensand, and not diffused throughout the clays, as in the Arkadelphia shales. In addition to the greensand, there is always a slight quantity of calcium carbonate, which is in the readily soluble form of marine shells. The quantity of both the greensand and the calcium carbonate is exceedingly variable, so that the preponderance of either or both, or their absence, may have much to do with the superficial weathering of the sub-strata. The yellowish color of the surface and kind of forest growth is to a great extent dependent upon the amount of greensand. The lime of these sands by its solution and redeposition as crys-

talline calcite, forms the local bands of hard limestone, such as the foundation of the county court house at Washington is built of, or cements the loose sands into the round coarse-grained boulder-like concretions characteristic of the formation.

In the western suburbs of Arkadelphia, where the Hot Springs road crosses Mill creek, the genesis of the soil from the High Bluff sands is well shown. Here the bank has been cut down in road building and the transition from the blue-green* and steel gray sands to the deep red or dirty sand color of the surface is apparent. The black grains of iron silicate (greensand) first oxidize on exposure into small, blood red blotches of hematite. The red color soon spreads through the sandy matrix, until near the surface the whole mass becomes a homogeneous red. The sands, upon drying, owing to the clay they contain, first cake, then crack, and finally, at the surface become pulverulent. The surface appearance of these sands is seldom of a deep red color.

Between Rome and Okolona, from three to five miles from the latter place is a typical surface exposure of these sands produced by the clearing of the forests. Here the whole surface has an olive tinge, and the hills are well rounded, though not precipitate. The creeks cut deep ravines, which have V shaped cross sections rather than precipitate bluffs. The region that surmounts Nacadoches bluff is a continuation of this, but it is densely covered with forests, and gives no indication of the substructure.

At Washington in Hempstead county the topography of the High Bluff sands is again varied, consisting of gentle undulations with deep ravines having well rounded sides. Here the greensand seems to be collected in definite zones, so that in places the sandy surface of the soil is pure white, or slightly

*The presence of minerals with a base of iron protoxide, such as glauconite gives some rocks a deep or bright green color. On exposure the silicate of iron is decomposed, silica is set free, and the iron plus oxygen and water makes hydrated peroxide. The rock thus loses its green color and passes into a yellow ash brown or rusty one. (Prestwich's Manual of Geology, Vol. i, p. 141).

tinged with red, while at others, as north of the railway station, it has a marked greenish tinge.

In general the High Bluff formation weathers into a sterile looking sand, which, however, owing to the potash and lime, is fertile, as is shown by the superb forest growth which covers it. The analyses on p. 220 show the composition of these High Bluff sands.

The Soils of the Big Deciper Formation.—This calcareous sand rock, which occurs in alternations with the lime marls, weathers readily into a loose sand, which, on account of the action upon vegetation by the lime, is first light yellow and then a black or chocolate color like the lime marls, and hence is known as the sandy black lands of the Okolona, Big Deciper and Washington regions.

Marl Soils.—The marls have the most characteristic appearance of any of the mesozoic formations, especially in regions which have been settled and cultivated for some time. Locally they are known as the "black," or "big oyster black lands," from the deep black color they exhibit upon the surface. The topography of these yellow marls is either that of broad flats or of greatly rounded, almost hemi-cylindrical or flat topped hills or ridges—the remnant of the former extent of these marls. Most of these have been washed away by erosion and denudation hastened by the crumbling properties of the lime, a process which is seen in operation on every hand. The sub-strata are blue or yellow calcareous clays of shaly structure, which first bleach white and crack into fragments, exposing the iron to oxidation; they usually turn yellow next, and finally form intense black surface soil. The blue and drab clays, first turn white upon drying, and owing to the excess of carbonate of lime, break into numerous pieces, a characteristic which gives them the popular name of "joint clays."

These so-called black lands are comparatively limited in Arkansas, however, being the northern limit of the formations from which they are derived. They are mostly confined to

the drainage areas of the Little Missouri and Terre Noir, the latter stream deriving its name from them.

The origin of these soils has been confusingly misstated by Dr. Owen* and others. Speaking of these "black" lands of the Trinity formation near Ultima Thule in particular, and all the "black lands," including the Okolona, or *Exogyra ponderosa* marls and the "rich woods," or Manchester shales, he says: "These black lands have the same origin as all the black lands I saw within the boundaries of the cretaceous formation, having been derived from a fresh water silt deposited in lakes, ponds and pools, that formerly existed in depressions and hollows of the cretaceous rocks; as is proved in almost every instance by the multitude of fresh water and land shells strewn almost everywhere along the border of these lands."

The numerous land and fresh water shells to which Dr. Owen here refers are all purely air breathing mollusca, which do not inhabit the water, but thrive upon the calcareous soils of these formations, where they may often be seen to-day by the million. They belong chiefly to the family *Helicidae* and to the spiral shaped genus *Bulimus*, and the familiar *Helix* or snail. It is the great resemblance of the former genus to the fresh water shells that is so deceptive. They are also often mistaken by some persons to be marine fossils.

The origin of these black lands is due to the excessive quantities of calcium carbonate in the lime marls, which, acting upon the organic matter of surface vegetation, causes rapid decomposition, and hence the intense black of the soil. This process is evident to anyone who observes the transition of color in the lime marls in a newly made ravine, where the lowest and purest substructure may be seen to gradually pass upwards from bluish white to yellow, and then into black at the surface. Such is the origin of the Okolona "black lands." While the shallowness of the surface soil, the bold contrast of color between the white and yellow subsoil and the black of the surface, may, at first sight, seem inimical to fertility, it is nevertheless a fact that the most fertile residuary soils of the

*See Second Report, pp. 112, 113.

whole cotton belt, including the central prairie region of Texas and the black prairies of Mississippi, West Tennessee and Alabama, have their geologic origin in this manner.

These "black lands," are often worn out by long cultivation or are unfit for it on account of the excess of lime, and are abandoned, so that many acres of what were once profitable farms may now be identified only by the absence of timber and vegetal life. These are sad commentaries upon the primitive system of agriculture whereby it was considered more profitable to exhaust the soils entirely and to clear new farms from the virgin forest, than to maintain fertility by cultivating protective crops, or by returning to the soil those ingredients of which it was constantly deprived. Such a policy is just as unwise for the farmer as if he endeavored to work his horses without feeding them. Most of the worn out "crawfish" lands, as they are called, are the more argillaceous strata of the Big Deciper formation, and the Koster "joint clays."

The Sandy Post Oak Lands, or Mulatto Sands.—West of the black lands of Clark county, occupying no connected area, are sandy lands of a very different character from those described as the residua of the Arkadelphia shales and the High Bluff formation. These lands are visible at Hearne Post-office, and in spots between that place and Antoine creek. They are characterized by the predominant growth of post oak, and the absence of pine. These soils owe their origin to the weathering of the blue marls of the Big de Gray formations. They also appear in the outskirts of the bottoms at the mouth of the Caddo, and along the military road in spots between that place and Hearne. The lower beds or blue dirt of the series, which are more sandy, weather into various sandy soils, the nature of which depends more or less upon the chemical composition and structural condition of these beds

The Soils of the Rocky Comfort Chalk.—The Rocky Comfort chalk weathers into very black waxy prairie soil of central Texas, which has great resemblance to the Okolona black lands, but in Arkansas there are only a few acres of the out-

crop, and these form characteristic bare spots with the white chalk looking like snow upon the ground. The process of transition from massive rock to the black soil is similar to that of the marls above described, but there is an essential difference in that the massive chalk first flakes off in large pieces on exposure, which become finer and finer towards the surface, and gradually change without any sharp demarkation in the soil, instead of first crumbling into the loose cubes of the joint clay of the upper cretaceous series. This formation is characterized by the growth of the *bois d'arc*, although that tree is not limited to it. Rocky Comfort is the most northeastern termination of this chalk which attains great development in Texas. According to Dr. Peters* "these soils contain so much carbonate of lime, that they may be considered marls rather than soils."

The Gryphæa Pitcheri Clay Soils.—The surface of the country underlain by these clays seems to be mostly poor lands forming pine flats, with a little hardwood upon them. The clays undergo no great change in color, merely losing their shaly structure and becoming a pulverulent dirt at the surface. They are sterile.

Soils of the Trinity Formation.—If there is any ambiguity about the surface appearance of the other formations, there is certainly very little about this. The constant strata of the yellow limestone and the blue and red gypsiferous marls declare themselves wherever the formation is exposed. I am not satisfied that the red marls of this formation are the result of superficial oxidization, but, upon the contrary, am inclined to believe that they, like the red beds of the far west, are original stratal colors. In tilled fields this formation is always readily distinguishable by the small sharp pointed oyster (*Ostrea franklini*), and the yellow character of the soil. The topographic contour is usually that of flats and alternating steps. Large slabs of flagstone are often left standing upon their edge, giving the erroneous impression that there has been some

*Owen's Second Report, p. 252.

great disturbance. The sandy soils of this formation are usually very poor and would be greatly improved by fertilizers. The few acres of Trinity "black (yellow?) lands" are somewhat richer residue, but they, too, deserve the attention of agricultural experimentalists.

The foregoing are the principal soils of Southwest Arkansas east of the military road, as far as my brief time could discover. Between these types there is an infinite variety of gradations, the one into the other. These possess every variety of fertility and sterility, to such an extent that it is no exaggeration to say that in no other area of its size in this country can there be found such a great variety of soils so well adapted to modern methods of agriculture.

TABLE OF ANALYSES OF ROCKS AND

	Hygroscopic Moisture.	Water and Or- ganic Mat- ter.	Insoluble Sil- icates, Sand and Silica.	Ferric Oxide.	Alumina.	Lime.
A. Transported Soils.						
1. Red river bottom, Red river parish, La.*	3 05	1 292	94 48	1 686	1 413	0 217
2. Red river loess (?), Little River county, Ark.†	7 750	3 631	89 040	2 340	2 710	
3. Red river, north of Cooke county, Texas*	9 982	6 998	72 383	4 681	8 861	0 761
4. Red river, north of Lamar county, Texas*	6 777	5 758	85 660	3 296	3 246	0 466
5. Red river, north of Chickasaw Nation, I. T.*	9 982	6 998	72 383	4 681	8 847	0 761
6. Red river, north of Choctaw Nation, I. T.*	9 566	4 906	77 913	5 274	8 848	
PRAIRIE D'ANE CLAYS.						
7. Grand Prairie, Prairie county, subsoil†	1 825	2 138	92 330	2 015	1 515	
8. Grey Prairie, Arkansas county, subsoil†		3 506	86 460	3 965	4 910	
9. Prairie Mer Rouge, Louisiana, subsoil*	2 648	1 606	94 086	1 781	1 798	0 127
B. Residual Soils—CAMDEN SERIES.						
10. Sub-strata, Cleveland Co., red land, Marks's place†	4 775	5 282	38 098	24 205	10 620	
11. Residual soil, Cleveland Co., red land, Marks's place†	4 001	5 547	63 690	23 605	5 066	
12. Cultivated soil, Cleveland Co., red land, " "†	4 500	6 806	69 690	15 959	5 985	
13. Gladly lands of Union county*.	3 675	6 618	90 715	trace	3 735	0 078
14. Arkadelphia shales, virgin soil†	11 150	8 216	68 315	6 350	12 910	
15. Ardadelphia shales, after cultivation†	9 865	7 443	73 040	5 600	9 010	
UPPER CRETACEOUS SERIES.						
16. Washington greensands (stratum)†	6 85	1 01	56 75||	17 63	5 78	
17. Washington greensands (stratum).....			56 75||	17 63	5 78	3 13
18. Washington greensands, selected marl†	3 54	2 55	64 88||	13 83	9 68	1 59
19. Greensand, Morris's Ferry, Little River Co., Ark.†.	5 46					
20. Blue marl, base of High Bluff, Arkadelphia†	2 17	4 27	75 52||	4 20	1 22	
21. Gryphæa vesicularis marl, Clark county, stratum†	11 025	16 352	64 015	5 015	8 935	
22. Gryphæa vesicularis, Clark county, soil†	5 575	4 691	44 040	4 650	6 735	
23. East of Hearne, Ark., Exogyra ponderosa marl†	4 30	2 90	37 44||		19 74	
24. Hollywood, Okolona, Exogyra ponderosa marl†.	2 15	2 59	53 07||	7 42	7 99	
25. Brownstown, Exogyra ponderosa marl†			41 72	4 86	4 26	
26. Chalk Cliff of Little river (chalk)†	0 55		3 49	1 41		
27. Rocky Comfort chalk†.....			9 77	1 25		
28. Rocky Comfort chalk, subsoil†	2 775	4 579	10 915	1 615	2 740	
29. Rocky Comfort chalk, soil†	9 675	12 005	37 990	4 415	6 165	
30. Rocky Comfort chalk, Waco, Texas*			11 451	3 648		
31. Rocky Comfort chalk, Austin, Texas§						
32. Rocky Comfort chalk soil, Collin county, Texas....	17 013	9 510	63 386	4 216	11 073	5 098
33. Rocky Comfort chalk soil, Johnson county, Texas..	11 460	6 255	65 917	5 346	5 746	1 388
34. Rocky Comfort chalk soil, Falls county, Texas.....	16 240	5 896	73 153	8 683	4 292	2 266
COMANCHE SERIES.						
35. Burnet county, Texas†.	0 180		1 590	0 41		
36. Lampasas county, Texas*	12 150	6 900	57 529	4 692	6 648	0 916
TRINITY SANDS.						
37. Pike county, Ark., subsoil	1 425	1 775	92 765	2 015	2 560	0 056
38. Pike county, Ark., soil.....	4 100	8 446	85 915	1 495	2 735	0 360
39. Comanche county, Texas, soil*	1 023	0 889	97 536	0 497	0 671	0 038

†Analysed by the Arkansas Geological Survey.

‡Analysed by Dr. Peters, published in Owen's Second Report.

||Total Silica.

SOILS OF SOUTHWESTERN ARKANSAS.

Magnesia.	Carbonate of Lime	Carbonate of Magnesia.	Soda.	Potash.	Sulphuric Acid.	Phosphoric Acid.	Brown Oxide of Manganese	REMARKS.
0 585	.....	.....	0 008	0 215	0 036	0 221	0 384	More homogeneous than residuary soils. An ideal soil, fertilized by annual overflows. Drainage difficult.
0.624	0.330	.....	0 088	0 852	0.062	0.256	0 165	A rich soil. Phosphoric acid the minimum component, sufficient. Productivity 2500.
2.623	3.879	.....	0 030	0 405	0 020	0 156	0.085	Minimum potash soils. Productivity 1500.
0.619	.....	.....	0 089	0 404	0 077	0.163	0 169	Minimum potash soils. Productivity 1500.
2 623	3 879	.....	0 030	0 405	0 020	0 170	0 085	Phosphoric acid, made available by lime.
1 217	1.992	.....	0.066	0 345	0.030	0.228	.....	Phosphoric acid, made available by lime.
0 265	0 046	.....	0.026	0 127	0 041	0 123	0.195	These soils are uniformly deficient in lime and potash, both of which can be cheaply supplied by using the cretaceous marls and Trinity gypsum.
0 526	0.093	.....	0 044	0.169	0 067	0 118	0 345	
0 238	.....	.....	0 085	0.155	0 210	0 093	0 135	
0 543	0 095	.....	0.067	0 248	0 050	0 297	0 495	Rich in iron, magnesia and phosphoric acid, but deficient in lime and alumina. Would be much improved by a dressing of 26, 28 or 29.
0 604	0 120	.....	0.075	0 227	0 058	0 413	0.595	This soil shows clearly the exhaustive process of cotton cultivation. See 11 and 12.
0.413	0 420	.....	.....	0.328	0 075	0.331	0.745	This soil is deficient in every element of fertility, and practically irremediable.—Loughridge.
0 208	.....	.....	0.036	0 035	0.062	0 096	trace	Old Buckner farm. An excellent soil.
1.737	2 640	.....	0 111	0.563	0 075	0.302	0 370	Old Buckner farm. An instance of exhaustive cultivation, as can be seen by comparing the analysis next above.
1 356	2 215	.....	0 106	0.396	0 084	0 191	0 445	Deficient owing to excess of sand and iron. Selected specimen for measurement of marls. An excellent potash marl for clay lands. Rich in potash and soda.
2 35	5 59	.....	0.380	2 28	trace	0 17	.....	
2 35	.....	.....	7 030	0 410	.....	0 17	.....	
2 43	.....	.....	0 99	3 06	.....	trace	.....	A good rich soil, with phosphoric acid minimum.
.....	40 76	.....	0 45	1 16	.....	0 26	.....	
0 660	5 46	.....	1 45	1 79	.....	.....	.....	
1 044	3 375	.....	0 900	0 311	0 144	0 165	0 545	An excellent marl, well adapted for adjacent non-calcareous soils. Rich in potash and lime, a good commercial marl. Rich in potash. Needs phosphates.
1 306	35 950	.....	0 109	0 454	0 170	0 234	0 345	
1 48	31 81	.....	1 53	1 96	.....	.....	.....	
.....	22 04	2.00	0 30	1 93	.....	.....	.....	From personal examination seems an excellent marl for adjacent sandy regions.
.....	46 73	1.51	.....	.....	.....	.....	.....	A pure chalk, which, owing to its proximity to navigable water, is very accessible to limeless lands of southeastern Arkansas and Louisiana.
.....	94 18	1.37	.....	.....	.....	.....	.....	A good type of black calcareous subsoil. Lime less than usual.
0.702	79 26	.....	0 099	0 135	0 118	0.112	0 140	
2 279	36 41	.....	0 146	0 362	0 247	0 368	0 290	
.....	82 512	1 189	.....	.....	.....	.....	.....	Black, waxy soil of Central Prairie of Texas. Shows uniformity of the Rocky Comfort (<i>Nio-brara</i>) chalk throughout its extent. No other fertilizers needed.
.....	96 34	.....	.....	.....	.....	.....	.....	
0 839	4 261	.....	0 186	0 619	0 104	0 131	0.409	
0 708	14 996	.....	trace	0 365	0 047	0 178	0 030	Fine black, waxy, minimum phosphoric acid soil.
1.394	2 459	.....	0 209	0 718	0 044	0 445	0.027	Fine black, waxy soil. An ideal soil. Rotation advisable
0.102	96.42	1.88	0 155	0.365	0 102	0 347	0 255	This formation has no areal extent in Arkansas.
0.283	21 704	.....	0.057	0 120	0.041	0 115	0 370	
0.562	.....	.....	0 035	0 153	0.092	0.163	0 295	
0.206	.....	.....	0 058	0 209	0 030	0 121	0.081	A typically inferior soil. Lime minimum, which is convenient.

*From Tenth Census Report on Cotton Production.

‡Calcium carbonate determined by Mr. R. H. Halley of the University of Texas.

CHAPTER XXII.

THE AMELIORATION OF SOILS.

A brief review of the present state of knowledge of the subject of the treatment of soils is essential to a clear presentation of the main object of this chapter, namely, to bring to notice and into use the valuable natural marls of the region discussed in this volume.

There are two principal methods of agriculture, and all others are but modifications of these. The first is the primitive nomadic or exhaustive method, whereby man takes the land as he finds it, cultivates it only by plowing or digging, as long as it will produce the one kind of crop which he desires to raise upon it, or which by tradition or lack of technical knowledge he has conceived to be the only one for which it is adapted, and depends upon nature for the rest. In the course of a few years both the land and its owner become impoverished, and all there is to show for the years of toil in clearing, breaking, cultivating and fencing is poverty for himself and his offspring. The victims of this system have been forced into nomadism, and they are constantly in search of new fields where they and their posterity may repeat the old process over and over again. The second method is that in which man exercises intelligence in selecting a soil, not altogether because of what it is, but in view of what it can be made, and creates and maintains its fertility by restoring to it what cultivated crops take away from it. It is by this process that the fertile soils of Europe and Asia have been maintained for centuries, and to this the agriculture of most of the United States is necessarily coming. The first method belongs to the frontiersman and pioneer; the second belongs to the present and future of our permanent civilization.

The time will inevitably come to any soil when it will become sterile unless the ingredients taken from it by the

plant are restored to it. Fallowing and rotation of crops may temporarily delay the disaster, but cannot avert it. The successful method of agriculture is, therefore, to create and artificially to perpetuate the fertility of the soil. Sometimes nature does this fertilizing by the distribution of sediments over the bottom lands, but even this is unreliable, and cannot compete with the fertility produced, by the exercise of human intelligence.*

Only a few words will be necessary to show how, by a simple use of the materials which nature has so bounteously placed at the disposal of mankind in the shape of the natural fertilizers contained in the different strata, together with attention to drainage, the present agricultural interests of Arkansas may be improved a hundred fold, and placed upon a permanent and profitable basis, while thousands of acres now sterile and useless may be made productive and habitable at but little cost.

The value of any soil to any crop depends largely upon its mechanical condition, such as porosity, which facilitates the distribution of moisture; friability, which admits the penetration of roots; tenacity (stickiness), the quality which enables the soil to hold the mineral ingredients during the time required for their decomposition or assimilation by plants. The mechanical qualities are attained by the proper admixtures of sand, clay and moisture, and by cultivation. The components of any soil which collectively constitute its mechanical qualities may be termed the matrix. Secondly, the value of a soil depends upon the contained amount and character of chemical fertilizing ingredients in a condition of solubility, so that they may be utilized by the plant. These are mostly mineral, such as lime, phosphates, potash, iron, etc. The growing plant abstracts these minerals from the soil, so that a

*It may not be inappropriate to quote here the recent statement of one of the oldest, most practical and successful farmers in America, Mr. Peter Henderson, the seedsman, who remarked that he had never seen a soil, however rich in nature, or in cultivation, that did not need fertilizing, and which could not be made more profitable thereby.

period inevitably arrives after the continued growth of vegetation upon any soil, when these fertilizing ingredients become exhausted, and the conditions favorable for plant growth cease.

The physical means of improving soils are of first importance, although seldom considered by most of our farmers. These, according to Wrightson, are :

1. Drainage.
2. Sub-soil plowing.
3. Clay burning.
4. Claying.
5. Marling, chalking and mixing.
6. Warping.
7. Ordinary cultivation.

But while these are all important means of improving the fertility of the land, it is in the province of the agricultural experiment stations which have been so liberally provided for by the United States government rather than in that of the Geological Survey to develop them. The question of drainage is of prime importance and it is hoped that the results of valuable experiments in this direction made in Clark county will ultimately be published in proper time and place.* So far as this paper is concerned, only the fifth method is within the immediate range of our present discussion.

*See reference to Major Jesse Ross's experiments in drainage and the manufacture of drainage tile on another page.

CHAPTER XXIII.

THE MIXING, MARLING AND CHALKING OF SOILS.

Where residual soils at one stratum are so excessively deficient or superabundant in some important ingredient as is the case with most of the upland soils of the cotton belt, these defects can be remedied by mixing with that soil some other which is rich in the desired material. This mixture may be solely for the purpose of improving the mechanical condition, such as would be the result of mixing the "joint clays" with the sandy lands, and *vice versa*, or for the purpose of supplying some chemical ingredient, such as the application of the greensands or lime beds of the *Exogyra ponderosa* marls to the Prairie d'Ane clays, which are deficient in these materials. In most cases both the mechanical and chemical composition of soils is improved by mixing. "The advantage of mixing soils of various characters together is illustrated on the grandest scale in nature when two or more geological formations contribute to the mass of a soil. Upper greensand when mixed with the marls of the superimposed lower chalk gives a soil of great natural fertility."* This process can be seen nearly everywhere in the mesozoic region of southwestern Arkansas.

Marls and Marling.—Geologically speaking, "marl" is a structural term, and not necessarily indicative of any particular chemical composition. A soft, earthy crumbling stratum of the earth's crust of any character—whether sandy, argillaceous, calcareous, or composed of any other predominating mineral, or vegetal humus, whether fertile or sterile—may be called a marl. Nearly all the strata of this region have a marly structure, but only a portion of them possess fertilizing ingredients sufficient to warrant their application in agriculture.

*Wrightson, p. 94.

Agriculturally speaking, however, marl is a natural mixture of lime and clay or greensand (glauconite), lime, and silica having the geologic marly structure above described. In general these mixtures are either predominantly rich in greensand or lime, as essentials, or in phosphates and other materials as accessories. Lime is usually the ingredient most desired.

Sometimes the marl is an almost pure chalk, in which case the process of dressing with it is termed chalking.

In every country where agriculture has attained its highest development marling is looked upon as a highly valuable means of amelioration and is extensively practiced. In England and continental Europe its use is general.

Certain marls have long been used as fertilizers in this country and with undoubted success and profit. In Pennsylvania and New Jersey they have been especially successful, and millions of tons have been used. On this Prof. Cook, the State Geologist of New Jersey, says:* "The marl has been of incalculable value to the country in which it is found. It has raised it from the lowest stage of agricultural exhaustion to a high state of improvement. Found in places where no capital and but little labor are needed to get it, the poorest have been able to avail themselves of its benefits. Lands which, in the old style of cultivation, had to lie fallow, by the use of marl produce heavy crops of clover, and grow rich while resting. Thousands of acres of land, which have been worn out and left in common, are now, by the use of this fertilizer, yielding crops of finest quality. Instances are pointed out everywhere in the marl district of farms which, in former times, would not support a family, but are now making their owners rich from their productiveness. Barren sands, by the application of marl, are made to grow clover, and then crops of corn, potatoes and wheat. What are supposed to be pine barrens, by the use of marl are made into fruitful land. The price of land in this region was considerably below that in the northern part of the State forty years ago; now that the lands

*Annual Report of the State Geologist of New Jersey for 1886, pp. 205, 207.

are improved, their prices are higher than those in the northern part of the State, though even there they are higher than anywhere else in the United States."

The Agricultural Uses of Greensand Marls.—In the winter of 1876-7, a series of questions was sent out to farmers in various parts of the State, with the request that they would return answers to them, giving their own practice and experience with marl. The inquiries were addressed to many, in order to get replies from enough to represent all the kinds of marls. A few of the answers are here given :

"We have improved land with marl that was so poor you could not raise anything on it, and now we can mow it and cut two tons of hay per acre, all by the use of marl. It will prevent sandy soil from burning up the crops and clay soil from baking, and insure crops on all kinds of land. My father bought the farm I now live on about sixty-five years ago. At that time marl was not much in use. He carted a few loads to try it, and said he could see it in the grass crops for years after, where he had put it on, which made him think it was of great value. He commenced to improve the land by carting 2000 to 3000 loads a year—his land, excepting 15 out of 150 acres, being very poor, so that he could not raise corn or grass at that time. Now we can mow every acre, and all through the use of marl. The land in my neighborhood is a sandy loam. By the use of marl it has become one of the best agricultural districts."

"My first experience with marl as a fertilizer was with that on Sharp's run, near Medford, Burlington county. About the year 1824 my father came into possession of a farm of about fifty acres on Sharp's run. A considerable portion of this was in meadow, underlaid by marl from eighteen inches to three feet beneath the surface. This meadow land had never, to my knowledge, been plowed. A large portion of, particularly the higher ground, was covered with Indian grass and moss, and was not worth mowing. Some of the lower part of this meadow produced good grass, white clover and herd grass. We commenced using marl, spreading it in the fall and winter,

at the rate of fifteen to twenty tons to the acre, on this moss and Indian grass, and instead of them we had a heavy swath of white and red clover, and that without any seeding. This ground has ever since continued to produce good crops, except in very dry seasons, although it has had only light dressings of marl at intervals of ten to fifteen years."

"All the good farmers adjoining us, who cultivate older lands, say that without marl they could not farm with profit, and this they prove by the great expense they are under to procure it, many hauling it twenty miles. They claim to be able to show, to a line, where it has been used."

"In 1824 I was induced to try the Squankum marl on an old wornout farm, much of which had not been plowed within the recollection of the oldest inhabitants. I applied five or six loads of twenty bushels each on an acre, for buckwheat or rye. The effect of it was so great that the use of it became general, and the farms increased rapidly in value from \$10 to \$100 or more per acre. As the land increased in value the amount of marl was increased to twenty loads an acre."

The Value of Greensand Marls.—From the valuable experience of fifty years or more of the uses of greensands in New Jersey, the following conclusions have been reached by the geologist of that state*: "From letters, detailing the results of experience, together with the chemical analyses, the following conclusions may be drawn:

"I. That the most valuable marls and those which will best pay the cost of long transportation, are those which contain the largest percentage of phosphoric acid. The phosphoric acid is combined with lime, and is partially soluble in citrate of ammonia, and its value may be safely set down at six cents a pound, and it can be computed by multiplying the percentage of phosphoric acid by twenty, which will give the number of pounds of that acid per ton, and that product by the price of reverted phosphoric acid, thus: If a marl contains 2 per cent. of phosphoric acid, a ton of marl will contain 20 times 2

*Report of 1886, pp. 209-210.

pounds, which is 40 pounds, and that multiplied by 6 cents per pound will give 6 times 40, or \$2.40 per ton for its value.

"II. That the most durable marls are those containing carbonate of lime, the more the better. The carbonate of lime is in the form of a very fine white earth or powder, and is much more valuable than that in hard shells. These are found in the lower marl bed, and in the upper portion of the middle marl bed.

"III. That the potash in the marls has but very little, if any, present value, it being combined with silica, and so insoluble.

"IV. The greensands containing but little of either phosphoric acid or carbonate of lime, become active fertilizers when composted with quick-lime.

"V. That marls which are acid and burning from containing sulphate of iron, can be rendered mild in properties and useful as fertilizers by composting with lime. A bushel of fine slaked lime if thoroughly mixed with an acid marl, is sufficient to neutralize the sulphuric acid in several tons. Its best effects are seen in wet seasons. It has produced the greatest increase of crops upon soils of rather heavy loam.

"VI. That crops particularly improved by it are all forage crops, grass, clover, etc.; for these the green marl may be spread upon the surface in the fall, to the amount of from 100 to 400 bushels per acre. The crop is generally doubled, and in some cases quadrupled, by this application. Other marls must be used in larger quantities, but will produce good results. *Potatoes*.—For this crop marl seems to be specific. It does not materially increase the growth of vines, and the yield is not much greater, but the potatoes are smoother and fairer in the skin, and dryer and of better quality when boiled. The marl is put on the potatoes in the hill at planting; if not acid it is thrown directly on the tuber; if acid, the potato is first covered by earth and the marl thrown on or beside that. From five to thirty tons may be used on an acre. *Buckwheat*.—Most remarkable effects upon this crop are produced by marl. Two and a half tons or fifty bushels to the acre spread on after sow-

ing, have caused an equal amount of buckwheat to grow on land which otherwise was not worth cultivating. Wheat, rye, oats and corn are improved by the use of marl, though not with the striking results seen on the crops before mentioned. It is applied as a top-dressing on the prepared ground, is spread on the surface before plowing, is worked in the hill or drill, or is composted with barnyard manure and spread on the ground, according to the farmer's judgment. From five to thirty tons and even more may be used upon an acre.

"With any kind of garden or field crop it may be used, and will be beneficial both to the crop and soil. It is free from the seeds of weeds, is dry, and convenient to handle, all of which recommend it to any good farmer. When first dug it may be somewhat lumpy, so as not to spread well, but after a few weeks exposure to the air it spreads perfectly."

Of the benefits derived from the use of such fertilizers in the State of North Carolina, Prof. Dabney says:* "The extension of the trade in fertilizers is intimately connected with the extension of cotton culture. The census returns show that the cotton production of North Carolina has more than doubled itself within the last ten years. With the aid of the superphosphates cotton has extended its domain forty or fifty miles up the slope of the Blue Ridge, and northward across the Virginia line. Upon the border of the natural kingdom of cotton, or the region in which the soils are warm enough and the seasons long enough to mature the cotton without any artificial aid, there lies a region, the northwestern boundary of which is still receding, in which cotton can be made to mature regularly and early enough to make a paying crop by the use of superphosphates, either alone or combined with potash salts. In this region the trade in fertilizers has grown to gigantic proportions. In towns where a few years ago only a few tons of superphosphates were sold, and not a bale of cotton was marketed, a large cotton trade is found now, and hundreds of tons of fertilizers are sold each season. The in-

*Report of the Agricultural Experiment Station of North Carolina, 1881, p. 23.

crease in acreage in cotton in our state last year was eight per cent. This is chiefly in the region mentioned. It is due entirely to the introduction of superphosphates, which will always be a necessity upon those soils."

The Agricultural Marls and Chalks of Arkansas.—No region of the world is more plentifully and conveniently endowed with such valuable natural marls and chalks than Arkansas, nor is there any region which could be so greatly benefited by their use. We have here large areas of soil especially deficient in the very ingredients which are so plentifully stored up in our marls. Many farmers endeavor to cultivate soils which are pure commercial marls, in which there is entirely too much lime, as in some of the black land regions, while others cultivate land utterly deficient in lime, potash, etc., which might readily be supplied by using the natural marls. Large tracts like the prairies east of the Iron Mountain railway, now lying idle, might be made the most fertile and profitable lands of the state.

The marls used most frequently throughout the world are of five general types, only one of which usually occurs in any single geographic area. These may be classified as follows:

1. *Phosphatic Marls.*—Those rich in phosphates, of rare occurrence and of great commercial value. Example, the tertiary marl beds of South Carolina.

2. *Greensand, or Glauconitic Marls.*—Those composed mostly of the mineral glauconite (a silicate of iron and potash) and sand. These are often comparatively poor in lime. Example, the marls of New Jersey.

3. *Lime, or Calcium Carbonate Marls.*—These marls are rich in lime as an essential, mixed with clay, greensand, or other accessory minerals. They form from 20 to 75 per cent of the material. Example, lime marls of England.

4. *Chalk Marls* are lime marls in which the calcium carbonate is so much in excess as to compose nearly the entire mass, usually over 85 per cent of the whole. Example, the chalks of England and France.

5. *Gypsum or Sulphate of Lime Marls* are those in which the fertilizing element is the sulphate of lime. This fertilizer is usually spoken of as land plaster.

All these kinds of marls seldom, if ever, occur in the same formation or in close proximity to each other, but usually each occurs alone in widely separated regions. Thus it happens that the marls of South Carolina are of the highly phosphatic character; those of New Jersey mostly greensands or glauconitic; those of England and France, mostly lime and chalk, while gypsum occurs at other places. In view of these facts it is very remarkable that in Arkansas, within a small triangular area of thirty miles square between Washington and Murfreesboro and the White Cliffs of Little river we have abundant supplies of at least four of these valuable kinds of marl, greensand, lime, chalk and gypsum, with the reasonable expectation that another year's investigation would reveal the phosphates. These facts alone, if properly utilized, will be of greater value to the state than all the gold dug within the bounds of California has been to that state.

The marls of Arkansas may be classified according to their local distribution as follows:

I. THE TERTIARY MARLS OF EASTERN ARKANSAS.

1. It has not been in the province of the writer's investigation to study the tertiary marls of Crowley's Ridge, and they are only mentioned here for purposes of comparison. As the value of marls is greatly dependent upon their convenience to the consumer, it is not necessarily derogatory to the local value of the tertiary marls of St. Francis and other counties to say that although valuable they are inferior to the cretaceous marls of the southwestern part of the state, possessing in general more sand and much less lime than the latter. These marls will be treated in other parts of the Survey's reports.

II. THE CRETACEOUS MARLS OF SOUTHWEST ARKANSAS.

2. The upper cretaceous or greensand marls found in the geologic horizon of the Washington or High Bluff sands, in

Clark and Hempstead counties, and in the beds of Little river, at Morris's ferry, in Little River county.

3. The middle upper cretaceous, or lime marls of the Big Deciper, *Gryphæa vesicularis* and *Exogyra ponderosa* horizons, varying in quantities of calcium carbonate and sand from 10 per cent. of the former and 50 per cent. of the latter as the geologic column is descended, to 75 per cent. of the former to 10 per cent. of the latter; and also varying in quantities of accessory clay and greensand. These marls occur in Clark and Hempstead counties at the horizons mentioned.

4. The basal upper cretaceous or chalk marls of the White cliffs of Little river, containing more than 90 per cent. of calcium carbonate and the Rocky Comfort chalk, containing more than 85 per cent. of lime.

5. The Comanche series, *Gryphæa pitcheri* marls at and south of Cerro Gordo, containing a little gypsum and much clay.

6. The Trinity gypsum marls of Plaster bluff and other points between Murfreesboro and Ultima Thule, containing from 10 to 95 per cent. of gypsum or sulphate of lime.

II. THE CRETACEOUS MARLS.

The Upper Cretaceous or Greensand Marls.—These marls are very siliceous, and the lime and greensand occur in local horizons or beds. Their chief value, if used for mixing, would be to loosen and supply phosphoric acid, iron and potash* to sandy and sticky clay lands. By reference to analysis No. 20 it will be seen that the potash in these marls is 3.06 parts in the 100. The lime can be regulated by selecting the fossiliferous or non-fossiliferous portions. The chief point of occurrence of these greensands is in the valley of Town creek at Washington, Hempstead county, where the greensand occurs in varying degrees of purity, accompanied or unaccompanied by shell beds, which are useful in case lime is also needed.

*Prof. Cook, State Geologist of New Jersey, doubts the potash in the greensand being of any value in the marls owing to its unavailable combination, but a study of the native forests of the Arkansas greensand region seems to indicate that this is the principal plant food contained in the greensands.

The same greensands occur in Clark county at many places, but as far as the writer's limited observations extend, in no case, so pure as those at Washington. The sandy surface residual soils of these marls, occupying an intermittent and limited strip from Arkadelphia to Columbus, are, no doubt, the finest soils possible for fruit trees and especially valuable for growing peaches. In this connection it is interesting to note that they present the same physical condition and occupy the same geologic horizon as the celebrated peach growing regions of New Jersey.

The greensand marl at Washington is especially convenient to railway transportation. If reasonable freight rates could be arranged, they should be freely used both on the plateau gravel or red lands, and on the Prairie d'Ane and Prairie de Roan clays and on the prairies of the eastern part of the state.

Only the general character of the greensand marls could be determined in the limited time devoted to the region, but more thorough and careful investigation, such as is in the province of an agricultural experiment station, would doubtless reveal much better results than the accompanying analyses.

It should be said that in no case have such rich and extensive beds of greensand been seen uncovered in Arkansas as occur in New Jersey, but as there is an inexhaustible supply for all purposes, this fact is of secondary importance.

ANALYSES OF GREENSAND MARLS FROM ARKANSAS, MISSISSIPPI AND NEW JERSEY.

The following table shows the composition of three specimens of the Arkansas greensands. Analyses of similar materials from similar geologic horizons in Mississippi and in New Jersey are given in the table for purposes of comparison.

	Water.	Silica.	Ferric oxide.	Alumina.	Lime.	Magnesia.	Soda.	Potash.	Brown oxide of manganese.	Sulphuric acid (anhydride).	Phosphoric acid.	Carbonic acid.	Loss on ignition.	Total.
1. Washington, Hempstead county, Arkansas. (a).....	6.85	56.75	17.63	5.78	8.13	2.35	.880	2.28	.....	Trace	.17	2.45	1.01	98.78
2. Washington, Hempstead county, Arkansas. (a).....	3.54	62.58	13.34	9.34	1.53	2.34	.95	2.95	.....	.....	.....	.....	2.45	99.02
3. Little River county, Arkansas. (a).....	5.46	.....	.....	.....	22.82	.....	.45	1.16	.....	.....	0.26	17.94	.....	.....
4. Monmouth, N. J. (b).....	10.00	38.70	18.63	10.20	9.07	1.50	.....	3.65	.....	.14	1.14	6.13	.....	99.16
5. Middle marl, Salem county, N. J. (b).....	7.39	51.50	21.04	6.01	1.26	3.95	.....	4.62	.....	.22	2.56	.....	.....	98.55
6. Upper marl, Squankum, N. J. (b).....	8.32	59.80	11.98	6.00	2.97	2.00	.....	4.25	.....	1.89	2.58	.....	.....	99.79
7. Clark county, Mississippi. (c).....	.....	45.88	13.02	7.75	14.785	2.476	465	1.717	.403	.566	.327	12.492	.....	99.833
8. Clark county, Mississippi. (c).....	2.559	38.22	5.626	2.602	28.167	1.482	166	978	.059	.005	.069	20.019	.....	99.952

(a) Analyses by the Geological Survey of Arkansas. (b) New Jersey Geological Survey. (c) Tenth Census (Hilgard).

Chalky or Lime Marls.—The lime marls of the middle beds of the upper cretaceous in Clark, Hempstead, southern Howard and Sevier counties are of great variety in composition, inexhaustible in quantity, and must be a source of great wealth to the agricultural industries of this part of the state in the future. The principal geologic horizons of these marls are the beds between the Washington greensands and the White Cliffs chalk, including the Big Deciper, *Gryphæa vesicularis* and *Exogyra ponderosa* marls, at innumerable places wherever these are the surface formations. The noted cretaceous black lands are, without exception, the immediate residue, or but slightly transported debris, of these formations.

The essential ingredients in all of these lime marls are calcium carbonate, usually in a chalky state of division, phosphoric acid and potash; the accessory ingredients, which would be noted in comparison with the soil to be treated, are sand and clay. Greensand is usually more or less abundant throughout. In general, these lime marls possess, in addition to all the virtues of greensand marls above described, a large and valuable percentage of the form of lime known as calcium carbonate. The following table of analyses of a few specimens of these lime marls from Arkansas and Mississippi will show their general character:

COMPARATIVE ANALYSES OF LIME MARLS.

	Organic and volatile matter.	Alumina.	Peroxide of iron.	Carbonate of lime.	Magnesia.	Carbonate of magnesia.	Phosphoric acid.	Sulphuric acid.	Potash.	Soda.	Insoluble matter and silica.	Loss on ignition and water.	Brown oxide of manganese.	Total.
1. An ideal agricultural marl (Lupton)	7.06	2.69	62.39	.66	Trace	Trace	Trace	Trace	Trace	Trace	9.57	Trace	Trace	100.
2. "Rotten Limestone" of Okolona, Miss.—A chalky marl-making limestone (Hilgard)	1.957	1.421	81.77	.877	Trace	Trace	Trace	Trace	.248	.321	10.903	2.840	Trace	100.062
3. A sandy lime marl from near Okolona, Arkansas	7.99	7.42	22.04	2.00	2.00	2.00	Trace	Trace	1.93	.30	53.07	4.74	Trace	99.49
4. A sandy lime marl from near Brownstown, Arkansas	4.26	4.86	46.73	1.51	1.51	1.51	Trace	Trace	Trace	Trace	41.72	Trace	Trace	99.08
5. A rich lime marl with phosphorus and potash (greensand) from the Boseman place, Clark county, Arkansas	4.961	6.735	4.650	35.950	1.306	Trace	284	1.70	4.50	1.09	44.04	1.046	.845	100.
6. Chalk from Rocky Comfort, Arkansas	Trace	1.25	88.48	Trace	Trace	Trace	Trace	Trace	Trace	Trace	9.77	Trace	Trace	99.50
7. A chalk from White Cliffs of Little river, Arkansas	Trace	1.41	94.18	Trace	Trace	Trace	Trace	Trace	Trace	Trace	8.49	0.55	Trace	101.00

IV. Chalk Marls.—The geologic occurrence in Arkansas of chalk has already been described at length in Part I of this report. There are two kinds of chalk marls in the state, that of the White Cliffs of Little river south of Brownstown, and that of Rocky Comfort, the former having over 90 per cent. of lime, and the latter over 85 per cent. Both of these localities are conveniently situated for the use of farmers upon large areas of land that would be greatly benefited by their use.

CHAPTER XXIV.

THE AGRICULTURAL USE OF CHALK AND OF CHALKY MARLS.

According to Wrightson, who has been followed in this paper as authority on practical agriculture, lime is "a constituent of all fertile soils, and an ingredient of all cultivated plants. The high proportion in which it occurs in the ash of many plants is sufficient to account for its value as a manure, while its mechanical and chemical effects upon the soil enhance its agricultural value. The following plants yield a preponderating quantity of lime in their ash, and have therefore been classed as lime plants :

"Percentage of Lime in the Ash of Certain Cultivated Plants.

Potatoes, steam and leaves.....	46.2	per cent.
Tobacco.....	67.44	..
Red clover.....	39.7	..
White clover.....	32.2	..

"Experiment has demonstrated that lime is absolutely necessary to the development of all plants, and the above list shows how largely it is appropriated by them.

"Application of Lime.—Lime is applied in two conditions, raw and prepared. When applied as marl or chalk it may be spoken of as raw or crude ; when subjected to burning or calcining, as prepared.

"Marl has already been defined as a mixture of clay and lime. It no doubt acts beneficially by virtue of both ingredients. It is applied at the rate of forty to eighty cubic yards per acre. The composition of marls is very various, some containing eight and others eighty to ninety per cent. of lime. They have been classified according to composition into true marls, or those in which calcium carbonate predominates, and clay marls, or those in which clay is the chief constituent.

"Chalk, especially when derived from the formation of the 'lower chalk'* is an exceedingly valuable addition to the strong lands and plastic clays, and in fact to any clay deficient in lime.

"Chalk is applied at the rate of twenty tons per acre in England, and is very effective. It is considered more lasting than lime. The effect of chalk is due to calcium carbonate, of which it is almost entirely composed, and to its accompanying phosphates."

The value of the fertilizing materials accompanying lime marls and chalk, as has been shown by many investigations,† is as great or greater than that of the lime, and hence it is that a good lime marl with phosphoric acid and potash is as valuable to some soils as the combined qualities of greensand marls and burned lime which in most countries are applied separately.

The closely adjacent distribution of the calcareous and non-calcareous soils of Arkansas, as can be seen upon the geologic map accompanying this volume, makes these marls trebly valuable to the people of the region, owing to the resulting low cost of transportation. They are also, in some cases, of such purity as to bear profitable transportation for several hundred miles by rail, and are well adapted to the reclaiming of the limeless lands of the eastern part of the state.

Gypsum and Gypsiferous Marls.—It hardly seems possible that within twenty miles of the excellent greensand and chalky marls above described there should exist excellent gypsum and gypsiferous marls, in a readily available condition, yet such is the case. In fact at the Plaster bluffs of the Little Missouri river, in Pike county, and at many other points along the southern boundary of the Trinity formation, there are beds of gypsum and gypsiferous marls of all degrees of purity and excellence, from pure saccharoidal gypsum to that containing from 10 to 20 per cent. of gypsum, and in quantities practically inexhaustible.

*Identical in age and character with the Rocky Comfort chalk of Arkansas.

†See remarks on use of marls, p. 227.

What has been said of the importance to the state of other deposits of natural fertilizers is equally true of these gypsum marls. They are important not only to Arkansas but to the whole of the southern cotton belt, in that they make this essential commodity several hundred miles nearer to its point of consumption than the sources from which it is now obtained from inferior beds in Ohio, Michigan, New York, and from foreign countries. The United States consumed in the year 1886 over 102,000 tons of land plaster and 98,000 tons of calcined gypsum, or plaster of paris, worth, in all, over a \$1,000,000 to the manufacturers, to say nothing of its incalculable value to the lands to which the plaster was applied.

While portions of these gypsum beds, as described in Part I of this report, may be of value for plaster of paris, provided they do not contain impurities, they are all remarkably adapted for agricultural uses as land plaster, which is of far more importance to this region.

It is hardly necessary here to expatiate upon the uses of gypsum to agriculture. It is used both as a mixture, a plaster or top dressing and for composting with manure. "As a fertilizer* it furnishes lime and sulphur to plants, and is thought to have the power of absorbing ammonia from the air and supplying it to the plant. To this important property Liebig ascribes much of its wonderful effect upon young grass and wheat. It has no caustic properties, like quicklime and guano, and, therefore, seeds are not injured by being placed in immediate contact with it. The vigorous, healthy start which it gives to the young plant is very desirable for both corn and cotton, since weak, sickly plants are almost sure to suffer from insects, or perish from other causes. This is one of the cheapest of fertilizers and should be used by farmers or planters who desire an increase of production by a moderate outlay of money."

Phosphatic Marls.—Thus far no phosphatic marls have been discovered in this region, but the age and nature of the rocks

*Lupton opinion cited, p. 74.

of Southwestern Arkansas lead us to believe that such marls may yet be found in the region.

Methods of Using Marls.—Dr. Eugene W. Hilgard, one of the leading authorities in America on agricultural chemistry, formerly State Geologist of Mississippi, and a man who has had great experience with marls analogous to those of Arkansas, has published some valuable deductions on this subject which are given on the subsequent pages. Before proceeding, however, it is necessary to briefly consider the chemical requirements and composition of agricultural soils and plants. All the matter composing plants is essentially derived from the air, water and soil, either in a gaseous, liquid or solid state, and in these conditions is known as plant food. In the use of marls, however, it is only the soil as a source of food that needs be considered. An ideal soil usually contains the following ingredients:

AN IDEAL SOIL.

<i>Potassium oxide</i>	0.2
<i>Sodium oxide</i>	0.4
<i>Calcium oxide</i> or lime	5.9
<i>Magnesium oxide</i> , or magnesia	0.85
<i>Iron oxide</i>	6.1
Aluminum oxide	5.7
Manganese oxide	0.1
Silicon oxide (sand, etc.)	64.8
<i>Sulphuric acid</i> , (anhydride)	0.2
<i>Phosphoric acid</i>	0.45
Carbonic acid or carbon dioxide	4.
Chlorine	0.2
<i>Organic matter</i>	9.7
Loss	1.4
	100.00

The calcium oxide or lime and carbonic acid usually occur as calcium carbonate or limestone, chalk, etc. The italicised substances are all essential to the soil, and, in the process of plant growth, are taken into its substance, as is shown in the

following table of analyses of the ash of some ordinary farm products :

COMPOSITION OF THE ASH OF PLANTS.*

	WHEAT.		Indian Corn.	Pota- toes.	Red Clover Hay.	To- bacco.	Cotton Plant.	Cotton Seed.
	Grain.	Straw.						
Potash	31.54	12.16	37.95	61.60	31.86	32.63	29.40	11.77
Soda.	2.66	1.00	3.00	1.00	2.16	3.81	1.7	3.20
Magnesia	12.10	4.00	7.50	5.00	12.16	12.10	6.9	5.99
Lime.....	3.14	6.82	3.40	2.40	31.09	40.15	23.3	2.05
Iron	Trace	1.02	.40	.85	.66	.....	9.5	.71
Phosphoric acid	48.50	3.20	44.80	17.67	9.00	3.74	18.3	11.41
Sulphuric acid	.08	5.78	1.50	6.25	3.03	4.02	1.7	.79
Silica	1.88	65.34	1.45	1.00	6.71	2.69	8.6	.11
Chlorine	.10	.60	Trace	2.23	3.33	.86	.5	.59

This ash, although containing most important and essential elements of the plant, is usually only from one to eighteen per cent. of the entire plant substance, as is shown in the following table :

PERCENTAGE OF ASH IN DRIED PLANTS.

Cotton lint.....	1.0 per cent.
Cotton seed	8.9 per cent.
Wheat grain	1.9 per cent.
Wheat straw	5.0 per cent.
Indian corn	1.5 per cent.
Red clover.....	6.8 per cent.
Cabbage	8.0 per cent.
Irish potatoes	4.3 per cent.
Turnips.....	10.0 per cent.
Tobacco	15 to 18 per cent.

The rest of the plant is composed of various organic substances formed by the combinations of the elements of the atmosphere, carbon, hydrogen, nitrogen, and oxygen. These are taken into the plant through its leaves or roots as water, carbonic acid gas, or ammonia. These are known as organic matter.

*This table, except the cotton, is taken from "The Elementary Principles of Scientific Agriculture," by N. T. Lupton, 1888, p. 29.

The remaining ingredients in the analyses of the soil, silica or sand, the alumina, or clay, are the mechanical matrices which hold the mineral food, and form the bases of all soils.

It is only the mineral elements of the ash that marls can supply, although in some cases, as with gypsum, by affinity for ammonia, they facilitate the procuring of organic food. Hence it is that while marls are essential to some soils, they have only a limited function. According to Wrightson (p. 104) there is a "possible limit to the profitable use of any manure. As long as a soil is deficient in a particular constituent, we may expect to see benefit from its application. If the land becomes sufficiently stocked with this constituent, we may find a change of fertilizers desirable. If a soil contains a sufficient proportion of phosphoric acid for the requirements of a wheat crop, and at the same time an excess of potash, we cannot expect a dressing of potash to be attended with any effect. A soil deficient in lime may be greatly benefited by an application of lime. But a second or third application of the same substance might produce but little effect, simply because lime had ceased to be a deficient element. Up to the present time, potash (owing to its existing in considerable quantities in farm-yard manure) has not been lacking in most of our soils. If, however, from the cultivation of the potato, the growth of wool, or the sale of straw, the amount of potash became reduced below the point required, then a demand for potash salts would immediately spring up."

"Liebig's 'law of minimum' springs naturally from the above considerations. Every field contains a maximum of one or several, and a minimum of one or several nutritive substances. It is by the minimum that the crops are governed, be it lime, potash, nitrogen, phosphoric acid, magnesia, or any other mineral constituent." It is by increasing the proportion of deficient constituents, and not by adding to the quantity of those in excess, that the effects of manures are rendered apparent. Hence the discordant verdicts with reference to the action of any particular fertilizer. Potash to a field deficient

in potash ; lime to a field deficient in lime ; but not lime to a field deficient in potash, is the proper course to pursue."

From the above statements the following brief facts should be considered before using any marl : No geologic marl, however rich in mineral ingredients can be expected to supply all the fertile ingredients of plant life. Stable manures can never be dispensed with. Marls cannot remedy the evils of bad drainage and neither is every marl applicable to every soil. In this connection it may be stated that, in general, it is a good plan to know what the soil needs before applying a remedy. Marls improperly used may prove an injury, and not a benefit.

The foregoing are the fundamental facts about the use of mineral fertilizers, and with these in the mind of the reader we can discuss the question of marls and marling so that it can be readily understood.

CHAPTER XXV.

METHODS OF USING MARLS.

[Adapted from E. W. Hilgard's treatise in the Geological Report of Mississippi, p. 252, and from other agricultural authors.]

Wherever marls containing the elements of fertility are convenient, let them be applied at once, regularly and systematically; marling every year a certain portion at least, of our lands, so that the whole shall have received a dressing in the course of from four to ten years, after the lapse of which we should begin again at the point from which we set out. Let us recollect that while in the use of stimulants (quick-lime, gypsum, etc.), in connection with subsoiling and fallowing, we have the means of relieving our immediate necessities, we cannot rely upon them for the future, and that each application of the former shortens the duration of the fertility, in precisely the proportion in which it increases our crops. A regular and constant succession of good average crops, which enrich slowly but surely, is certainly preferable to a brief period of brilliant crops, followed by exhaustion of the soil. And while, in this respect, each one must be left to judge and act according to the stringency of his own particular case; yet let him recollect that the time will surely come when we shall have to yield obedience to the inexorable law, that *no land can be permanently fertile unless we restore to it, regularly, the mineral ingredient which our crops have withdrawn.*

Limited Duration of the Effects of Marling.—This consideration leads us to understand, also, the cause of a phenomenon which has given rise to many discussions, and fruitless attempt at explanation, so long as marls were considered as owing their efficacy merely to the lime they contain. It was found that the period during which the effects of a dressing of marl continued, was much more limited than the slight waste of lime from the soil would justify; analysis, moreover, proved an

abundant supply of lime still to be present in the soil ; and nevertheless it appeared to have lost its efficacy. A higher degree of accuracy in chemical analysis, which we have since attained, has enabled us to detect in marls formerly regarded as purely lime, other of the nutritive elements of plants, the presence of which had before been overlooked. Their quantities, it is true, are sometimes extremely minute ; but not more so than are the respective amounts of the ingredients withdrawn from our fields by crops.

If a dressing of 200 bushels per acre, of marl containing 40 per cent. of lime, and $\frac{1}{4}$ per cent. of potash, and the same amount of phosphoric acid, ceases to be effective (and therefore requires to be repeated) in the course of ten years, as might be the case in practice, it is very plain that its want of efficacy cannot be attributed to the slight diminution of the lime introduced by the small amount which our crops have withdrawn. Not so, however, with respect to potash and phosphoric acid, for in case of heavy cropping the amount of these substances contained in crops would form a large percentage of the whole quantity introduced in the marl, quite sufficient to explain the inefficacy of the latter beyond the period stated. (Hilgard, p. 231.)

As in the case of the cretaceous marls, the green and blue marls of the tertiary are, as a general thing, richer in potash and poorer in lime, than the white marls. The former are therefore to be considered rather more in the light of true manures, the latter rather as stimulants. None of them, however, are entirely devoid of potash.

Marling.—As to the mode of applying the marls just described, little need be added to the general rules already given. They ought to be scattered broadcast, as a general improvement of the land, not in the drill ; and whenever practicable, they ought to be used in conjunction with vegetable matter.

The very precept of broadcast scattering necessarily involves the condition, that the material should be in a certain state of comminution ; not in blocks or lumps, as it comes from the pit. In most cases, exposure to a few rains will cause

the material to crumble sufficiently for all purposes. It is only the white marls of the tertiary, which sometimes resist this treatment, and require to be pounded, which is rarely, however, an operation of any difficulty. Generally the marl may be hauled to the field as it comes from the pit; being thrown from the carts in small piles, it will be in a favorable condition to be acted upon by the weather, especially in winter; it may then be scattered and turned under by the first plowing in the spring. Plaster is often applied to grains as a top dressing.

With most of the bluish marls this preliminary exposure becomes a matter of great importance, and often of necessity, on account of their frequently containing small amounts of iron pyrites. This mineral, by the action of the atmosphere, is transformed into green vitriol or copperas, and as such would, for the time being, prove highly injurious to plants, causing "dead spots" wherever a crystal or lump of mineral thus decays. In the presence of a plentiful supply of lime (with due access of air), however, the copperas would be rapidly transformed into gypsum or plaster, and inert protoxide of iron; thus adding a useful ingredient to the components of the marls. This renders the previous exposure or weathering of the marls doubly important. (Hilgard, p. 460.) As to the quantity of marl to be used so much depends on circumstances that it is difficult to give any general rule in regard to it. On heavy clay lands, and such as contain a large supply of vegetable matter, "overdressing" will not readily come to pass. Dressings of 300 bushels per acre, of marls containing 40 per cent. of carbonate of lime (and proportionally less of those containing a higher percentage) are quoted by Mr. Ruffin, in his "Essay on Calcareous Manure," as being unobjectionable on soils moderately heavy, while on very heavy land dressings of 500 to 600 bushels was no over-dose. Within these limits, a little more or less, the duration of the effect of marling will be approximately proportionate to the quantity employed. That is to say, if the perceptible effect of a dressing of 300 bushels will last fifteen years, that of 100 will last about five years. This, of course, is only very approximately

true ; in the example just quoted, for instance, the effects of the 100 bushels would not be so prominent at any time as that of 300 bushels, and would, therefore, be likely to last longer in proportion. Every individual must judge for himself whether it is more profitable for him to apply a heavy dressing at once, or lighter dressings in more rapid succession.

Overdressing with Marl.—On sandy lands, poor in vegetable matter, overdressing happens more easily, and must be guarded against. If at all practicable, the marls ought to be composted, or, at least, applied conjointly with vegetable matter of some kind ; most conveniently, in many cases, by being turned under with green crops. The effects on a corn crop, of overdressing with calcareous marls, is described by Mr. Ruffin to consist in paling, yellowing and final drying up of the young plant during the months of May and June. Stable manure, or decaying vegetable matter is stated by him to be an effectual remedy; even as, if applied from the outset, it is a certain preventive.

As it would not come in the province of the present report to give this subject a discussion as special as might be desirable and proper in the final report, I would refer those who intend to practice marling on a large scale, to the work of Mr. Ruffin above quoted, which contains useful practical rules and a vast amount of information on this subject.*

*Hilgard, p. 461.

CHAPTER XXVI.

HYGIENE AND DISINFECTING RESULTS OF MARLING.

Over and above the favorable effects of liming and marling on the productiveness of soils, another result is often experienced in districts where marling has been practiced on a large scale, viz.: the improvement of the general health of the region, especially where the soils are acid and well drained. This effect may be understood in some measure when we recollect the disinfecting and deoderizing powers possessed by burnt lime—frequently used for that purpose in sewers, cess-pools, hospitals, etc. The effect in this respect, of marls, or carbonate of lime, is, of course, less energetic than that of burnt lime, but it exists none the less, and the general use of our marls for these purposes, would not be among the least benefits conferred by them on the population.

Gypseous Marls.—This class of marls contains the sulphate of lime instead of the carbonate of lime, and according to Wrightson "is another form in which lime is employed as a manure. It is occasionally applied at the rate of from 2 to 10 cwt. or more per acre to clover and other leguminous crops. It may also be employed to fix the ammonia in ordinary farm-yard manure, by scattering it over the floors of stables and upon manure heaps. Gypsum is an inseparable ingredient of all superphosphates, in which it exists as one of the results of the application of sulphur trioxide to phosphates abounding in lime. A dressing of 5 cwt. per acre of a good superphosphate necessarily involves the application of about 2 cwt. of gypsum." (Wrightson, pp. 133-134.)

The foregoing dwells but little upon its chief virtue which is that of its fixing the evanescent ammonia. It is usual to sow it broadcast over wheat and grass, during the early spring, and to drop it with corn at the time of planting, or to drop a small portion on each hill of corn after the corn has been

thinned. Corn moistened with water and rolled in plaster at the time of planting will get a more vigorous start, and be the better enabled to stand an early drought. Cotton seed may also be very advantageously rolled in plaster previous to planting. For this purpose the seed is placed in a tub of convenient size, thoroughly moistened with water, the plaster added, and the whole well stirred. As much as will adhere is dropped with the seed.

It is not necessary to mix gypsum with superphosphate, because in the process of making superphosphate from bones, calcium sulphate (gypsum) is always formed at the same time, and constitutes a large portion of the superphosphate.

In general the same rules which apply to gypsum as manure, will hold true in the case of gypseous marls; unless indeed, analysis should show them to contain other ingredients which could essentially modify their action.

Use of Marls in Composting.—Few substances can be better suited to the purposes of composting than the calcareous, and no less the gypseous marls, before described; and for this purpose, the clayey (in contradistinction to the sandy) varieties of both ought to be selected by preference. The mode of action of gypsum in fixing the ammonia of the atmosphere, has already been referred to; and its effects, when used as a composting material, are equally favorable. In many cases where the direct application of gypsum to land is too expensive* in proportion to the effect produced, it may be made to pay exceedingly well, when used as composting material—not only with stable manure, but also with cotton seed, that peculiarly southern fertilizer. It has been observed by agriculturists, that decayed or “rotted” cotton seed is much inferior in value as a manure, to the same material when applied in the fresh state. The odor evolved by cotton seed when decaying, leaves little doubt as to the cause of this deterioration; a great deal of ammonia escapes into the air, leaving behind the mineral ingredients only, with some

*This material is too pure and too plentiful and too convenient in Arkansas to ever be considered expensive.

humus. These, in the absence of ammonia, act much more slowly, and do not, therefore, produce so obvious an effect upon one and the same crop, as the fresh seed would have done while decaying in close contact with the living plant. By the proper intermixture of the seed with some plaster, when piled up for preservation as a manure, the ammonia may be retained, and the effective value of the material essentially increased.

The Applicability of Arkansas Marls to the Soils, and the Necessity of Experimentation.—After the general remarks in this work, the geologic origin, stratigraphy, distribution and composition of the soil making formations the part which marls can play in their alteration for agricultural purpose will be readily apparent.

The transported alluvial soils are usually more homogeneous than the residual, and the applicability of marls to them must be decided by individual analyses.

The later post-tertiary soils, such as the prairies of eastern Arkansas and Prairies de Roan and d'Ane, seem in general deficient in lime and potash, and to them the application of the lime and greensand marls, such as occur throughout the area of the upper cretaceous, would be of inestimable benefit, and double, if not treble, their market and agricultural value.

The older plateau gravel red lands are an excellent mechanical matrix for all kinds of fertilizers, and owing to their close proximity to lime, chalk and gypsum, and their hygienic situation, they are susceptible of the highest culture and improvement. The red lands of the Camden series, by addition of the lime marls and chalks, could be made ideal soils. The sterile sands of the upper Camden series could be improved a hundred fold by a dressing of common clay, while the more argillaceous fertilizers would be of inestimable benefit. For the sticky rich woods a dressing of the convenient greensands would be highly profitable.

Since the cretaceous soils are practically the residua of the marls we have been describing, it naturally follows that these lands do not need the application of mineral fertilizers,

or, if at all, not to the extent that the vastly greater areas of tertiary and post-tertiary lands do. On the contrary, they need organic manures to modify the effect of the lime and other minerals they contain. The mixing of sands with clay lands and clays with sandy lands, however, could be practiced with much profit in some cases. Nature, by mixing, has produced in the cretaceous black lands a beneficent example which it would be well for man to follow.

The Trinity residual soils, although rich in gypsum, could be quadrupled in value by dressings of the potash and phosphorus bearing greensand and lime clay marls of the upper cretaceous.

The unclassified residual soils of the remainder of the state, many of which are undoubtedly deficient in lime, are especially in need of such marls and chalks as we have described, and they should be transported by the hundreds of car loads for that purpose. Gypsum could be applied to the soils of all these formations with great profit.

Concluding Remarks on Marls.—Before marls are extensively applied preliminary experiments should be made with them. Often individual farmers may try these marls, but from lack of experience, such as applying some marls in a poisonous condition, before the pyrites of iron has been oxidized by weathering, etc., they often obtain negative results, and thus really valuable marls may be prematurely condemned as worthless. What the whole region needs is an agricultural experiment station, properly supplied with apparatus, which will perform every possible experiment with every possible marl upon every possible soil and product of the region. By an agricultural experimental farm, I do not mean a place for the education of youth, but for the benefit of the immediate material improvement of the whole agricultural population present and future of the region in which it is located; a farm where every possible endeavor will be made to ascertain the effect of every human effort to find out the best fertilizers and crops and how to treat them. Such an experimental farm is a positive neces-

sity, and the farmers of the region neglect their own interests if they do not aid in its immediate establishment.

No place is so conveniently situated for this experimental farm as Nashville, since its clay soils are especially adapted for experiments with fertilizers and drainage, and it is situated most conveniently to the gypsum, greensand, chalk and lime marl beds, while the citizens of the place would no doubt provide the necessary land.

CHAPTER XXVII.

THE ECONOMIC PRODUCTS OF THE REGION.

The Forests.—In no portion of its vast extent does the great Atlantic timber belt reach a grander perfection, either in the number of its species or in the size of its individuals than in the southwestern portion of Arkansas. As a natural result of its diversified non-consolidated formations this region embraces a wonderful intermixture of areas of both pines and hardwoods, the former usually occupying the more sterile lands of the post-tertiary and Trinity areas, while the latter occupy the broad flood plains or the rich lands of the upper cretaceous series. In fact the geologist, with a little experience, can readily trace most of the formations here by the character of the forest growth.

Without dwelling upon the scientific enumeration of species, it is only necessary to state here that in this limited area there is a most available and valuable lumber supply, including not only the superb pineries, but extensive areas of ash, hickory, oak, gum, cypress and holly, the last mentioned tree reaching an unusual size and growing in the greatest profusion along the bottoms of the Little Missouri.

Tree Culture.—It seems almost paradoxical in this region where trees reach such a climax of perfection to bring up the question of tree culture, but in traveling through certain districts, both here and in Mississippi, where the famous black walnut cuts of a few years ago were made, it is a constant and ever apparent fact that the planting of walnut trees would be not only of great intrinsic value but would aid in reclaiming and saving for future generations the old exhausted black land fields, the valuable marls of which are so rapidly washing away.

The hardwood forests of this region are the most valuable of all its natural products, but they are being wasted rapidly.

The chief factors in this destruction are, first, the destructive method of agriculture whereby lands are worn out, causing the unnecessary clearing of thousands of acres of new farms; second, its unnecessary destruction, such as the cutting down of holly trees that the cattle may feed on their foliage; the method of using only the smaller timber for fuel and leaving fallen trunks to rot; and the habit of destroying superb trees for trivial purposes.

It is evident that these forests must increase in value as time goes on, and we only need to save what we have in order to avail ourselves of this value.

Iron Ores.—The iron ores of the southern and southwestern portions of this state will be carefully studied and reported upon in a future volume of the Geological Survey's reports, and for this reason no mention is made of them in this place.

Clays.—The clays in themselves are worthy of far more extended study than has been possible to give them. Throughout the region there is an abundance and great variety of clays suitable for all the commoner uses of that material, such as the manufacture of tiles and ordinary pottery, and in the Camden series especially there are clays that seem adaptable to the higher ceramic uses. Potteries for the manufacture of glazed earthenware are in operation at Benton, Hope, Malvern, Texarkana, and at other places in the tertiary area, but none have been heard of in the cretaceous area, nor is it probable that there are any, although the Indians undoubtedly used these in some of their pottery. Kaolinities are frequently reported, but the writer has had no opportunity of seeing them. They are worthy of further investigation. Everywhere throughout the region clays are easily accessible, and of sufficient value for drain and chimney tiles, which in the future will come to be used.*

*Major Jesse Ross, of Clark county, has conducted, at his own expense, a series of experiments upon the clays of that county, with a view to finding an economical material for agricultural drainage tile, and has met with much success. He has erected upon his place a tile factory, and now manufactures tiles successfully for use upon his farm.

The clays of the upper cretaceous series are too much impregnated with lime to be of much value for pottery. These cretaceous clays may, however, be of much value in making hydraulic cements.

Building Material.—It is hardly necessary to state, after the many references in the preceding pages to the soft and disintegrating character of the substrata, that the region is deficient in building stone. There are a few bands of limestone and impure sandstones in the High Bluff formation, but the former are local and exceptional, and the latter of no value for even the crudest uses. In the Trinity formation, however, the thin beds of hard limestone could be made to serve many of the cruder purposes of building, such as foundations, chimneys and stone walls, but would have no value for export, or other than local use.

A remarkable local development of chalk at the White Cliffs of Little river would make one of the purest and whitest limes of any rock in the United States, and the locality is readily accessible by river transportation to the Iron Mountain railway at Fulton. When it is remembered that nearly all the lime used in this portion of Arkansas is imported from Alabama and Missouri, it seems strange that this local supply should remain undeveloped.

At Okolona, Brownstown and other places an argillaceous lime marl is used for fire backs and hearths, cistern linings, etc.

The chief value of the lime products, however, is in the agricultural marls, which are discussed elsewhere.

Gypsum.—The Trinity formation is rich in gypsum and gypsiferous marls, the latter too impure for the arts, but suitable for an agricultural fertilizer or land plaster. At the gypsum bluff, or "plaster bluff," as it is familiarly called, two and one-half miles south of Murfreesboro, in Pike county, there are strata of pure saccharoidal alabaster, from 6 inches to 6 feet in thickness, with seams of satin spar. This gypsum is sufficiently pure to make plaster of paris, as well as fertilizers, and will no doubt be a source of much wealth to the county some

day. The same geologic horizon as that containing the gypsum beds on Little river outcrops sparingly at many points along the southern scarp of the Fort Towson road valley.

Salt and Salines.—One of the most valuable economic products of the region, if developed and utilized, would be the saline waters, such as those of the Ouachita bottoms, in townships 6, 7 and 8 S., range 18, and 19 W. These are found in sloughs and surface wells in nearly all the alluvial bottoms between the mouth of the De Roche and L'Eau Frais. They were formerly utilized for the manufacture of salt by evaporation, especially during the civil war, when the Confederate States government manufactured here millions of bushels for the whole trans-Mississippi region. There are also salines at Deciper lick, Deciper lake, and at the Terre Noir Methodist camp ground in the northeast quarter of the northeast quarter of section 6, 3 S., 21 W. The amount of salt in the waters of the principal salines of the Ouachita bottoms is reported to be from 9 to 20 per cent. These salines are worthy of more careful study and investigation than the Survey has been able to give them.

Salt wells were profitably worked in other localities throughout the belt between Arkadelphia and Ultima Thule before the people so completely resigned all domestic industries to foreign hands. The source of this salt is probably in the Trinity beds, for in all cases the stratigraphy points to this conclusion.

Other extensive salines have been worked in the second bottoms of the Saline in Sevier county, as noted by Owen, and although flooded by fresh water when visited by the writer, traditions of the neighborhood and signs of former extensive work on the spot indicate a high degree of salinity.

There are other salines at Cerro Gordo, in Little River county, and on the Rolling Fork near Chapel Hill, in Sevier county.

Lignite or Brown Coal.—Lignites occur throughout the Camden series as a part of the lignite belt of the Gulf States. Below is given an analysis of a sample of lignite taken from

the "Van Sickle mine," five and a half miles north of Stephens, on the northwest quarter of section 36, 14 S., 19 W. It was collected and sent to the Survey by Mr. F. E. Morgan, of Stephens Ouachita county. For the purpose of comparison there are introduced here analyses of lignites from other parts of the world and also of three qualities of coals:

LOCALITY.	Water.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash.
Lignite or brown coal, Van Sickle mine, Ouachita county, F. E. Morgan, collector	30.58	31.09	28.56	0.65	9.10
Lignite, Devonshire, England	34.66	68.08	27.34	2.36	2.27
Lignite, Thallern, Austria	22.53	35.02	41.08	4.56	19.34
Allister slope, Coal Hill, Arkansas	1.17	10.47	76.49	3.53	8.82
Baxley coal, Paris, Arkansas	1.23	15.74	75.33	2.40	5.28
Pennsylvania anthracite	3.03	4.36	85.73	1.01	5.85

From these analyses it will be seen that as lignites go, the sample analyzed may be regarded as a very good one. The great objection to all lignites, however, for fuel purposes, is the large percentage of water which they contain, for the evaporation of this water must absorb a considerable part of the coal's calorific power. The low percentage of sulphur in this specimen is so much in its favor, for one of the objections frequently urged against lignites, is the disagreeable odor caused by the high percentage of sulphur present.

These lignites have occasionally been used for fuel upon steamboats and in the furnaces of engines and cotton gins, and their use is now being rapidly extended. The brown coals of the southern portion of the state will be carefully studied and reported upon by the Geological Survey in a future volume.

Mineral Springs.—The waters of the region are more or less impregnated with mineral salts, especially lime, in the cretaceous area, iron in the tertiary and post-tertiary lands, and common salt, Epsom salts, etc., in the Trinity sands. Of course

analyses could not be made of these waters up to the present time. Concerning the medicinal value of springs in general, the following words of Dr. Hilgard are very applicable :

"It cannot be too strongly urged upon the inhabitants of these regions that the habitual use of mineral water proper of any kind is no more rational than would be the habitual use of any other medicine with persons in a normal state of health. It is often said that mineral waters are 'nature's own remedy,' which may be true enough, provided there is something to be remedied. The Epsom salt, Glauber's-salt, gypsum, etc., contained in these waters are no less purgative, debilitating, and therefore injurious to persons in good health than the same articles are when derived from the druggist's vials."*

The chief impurities in the waters flowing from the Camden series seem to be iron and petroleum. Dr. Hilgard has observed that in Mississippi similar waters to those of the yellow uplands which are very much impregnated with iron, lose much of the iron after the timber is cut from the drainage area where they originate.

Many of the wells in the Ouachita bottoms are so impregnated with salt as to be unfit for domestic use.

In the blue marl region lime and bituminous matter often render the waters unfit for drinking purposes.

The best and purest waters of the region are found in the post-tertiary beds, especially of the plateau gravel, a fact which adds much to the superiority of that formation as a place of residence, and one which has long been apparent to the older inhabitants.

*Report on the Geology and Agriculture of the State of Mississippi, p. 286.

THE NORTHERN LIMIT OF THE MESOZOIC ROCKS IN ARKANSAS.

By O. P. HAY, PH. D.

In order to determine as accurately as possible the northern limits of the rocks of the mesozoic age in Arkansas, the writer was requested by Dr. Branner, State Geologist, to locate this northern border during the summer of 1887 through the region lying between the Ouachita river near Arkadelphia and the Indian Territory line near Ultima Thule. In this work he was accompanied and assisted by Mr. Chas. H. Bollman, a volunteer on the Survey, from the University of Indiana.

After spending a few days in the neighborhood of Arkadelphia in company with Dr. Branner in studying the peculiar features of the neo-paleozoic contact in that vicinity, and such other sections as we were fortunate enough to meet in our search after the northern edge of the formation, Mr. Bollman and myself started west on the 14th of July, 1887. The distance from Arkadelphia to Ultima Thule is only eighty miles, but fully a month was consumed in making the survey. Much of the territory had to be traversed again and again before we could determine satisfactorily the line of parting between the cretaceous and the older rocks that lie toward the north; and in this too sparsely settled country, covered with forest trees and shrubbery, often rocky and hilly, and overspread with the materials resulting from more recent geologic changes, progress was necessarily slow and the work difficult. Having some baggage and collections of fossils to transport, our advance from point to point was by vehicle of some kind; but the ground was all carefully retraversed, occasionally on horseback, but for the most part on foot. After reaching Ultima Thule we returned to Howard and Hempstead counties and spent

some time in investigating the geology of the country in the vicinity of Nashville and Washington, after which the writer returned to Arkadelphia and again went over the line as far west as the Terre Noir with the result of finding the limits of the cretaceous some miles further north.

At all points where rocks were fossiliferous we endeavored to make as complete collections as our time would justify, in order that the Survey might have the means of illustrating the life that prevailed when these rocks were being deposited, and at a time when life began to take on a more modern aspect.

GENERAL FEATURES OF THE NORTHERN BORDER OF THE MESOZOIC.

The northern edge of the mesozoic deposits of Arkansas, west of the Ouachita river, lie up against an older formation that is referred by Dr. Owen to the millstone grit, a series mostly of sandstones and shales underlying the productive coal measures. Dr. Branner concurs in a provisional reference of these beds to the lower carboniferous, but on account of the absence of specific data upon this subject he prefers that they be spoken of in this paper simply as paleozoic deposits.

Along the area where these paleozoic rocks now come in contact with the mesozoic the former were originally mostly beds of sand or soft sandstone and of impure clays, all in horizontal positions. Afterwards, however, and before the mesozoic rocks were deposited, these paleozoic strata were subjected to the action of various forces and agencies which have greatly altered their arrangement and structure. By lateral pressure they have been thrown into a succession of folds, which run in an approximately east and west direction, while denudations has removed the summits of these folds so that the edges of these beds are now often found dipping to the south or the north at a high angle, or even standing perpendicular. While these movements were in progress, the internal structure of the rocks underwent more or less alteration. Through the pressure to which they were subjected, heat, and probably water charged with alkaline solutions, the sandstones were converted into hard, brown, yellow, gray, and white

quartzites, and the beds of impure clays into hard shales, and sometimes into true slates. Later these folded and metamorphosed strata formed the shore against which beat the waves of the mesozoic sea, and in this sea gradually accumulated beds of limestone, clay, and sand. These beds, originally nearly horizontal in position, have been little or not at all disturbed since the time of their deposition. The mesozoic shore line did not follow a direct course, but here and there it projected out in the form of capes and headlands, or was penetrated by bays and estuaries. Had it not been for subsequent events, the junction between the paleozoic and the mesozoic deposits would have been easy to trace, but it is evident that at some period, not far removed geologically from our own time, strong currents of water have swept over the old shore line, and in most places covered it with many feet of clay, gravel and cobblestones. While, therefore, it is often possible to discover outcrops of the two formations within a few rods of each other, in other cases it is difficult or impossible to do this. Recourse must often be had to the results of well-digging, since in seeking water the overlying deposits may be passed through, and either the mesozoic or the paleozoic rock reached. In some places, however, there is a strip two or three miles in width along which the line separating the two formations cannot be determined with certainty. The determination of its exact position must depend on future observations, and all persons living along the border who have occasion to dig deep wells may contribute to this result.

The two formations referred to above, the paleozoic and the mesozoic, having been deposited at such widely different times and having had such different histories, have produced each its own distinct effect on the topography, the soil, and productions of the country. North of the border-line the surface rapidly rises into rough hills, which soon become mountains of low elevation. These hills are to a great extent composed of red clays charged with gravel and other water-worn material, but through the clay the truncated folds of quartzite frequently appear, forming prominent ridges. This region gives

rise to numerous clear and rapid streams, which flow in narrow and rocky channels, those of Clark and Pike counties flowing southeast into the Ouachita, those of Howard and Sevier counties flowing toward the south into Red river. As examples of these beautiful mountain streams may be mentioned the Caddo, Clear fork of the Little Missouri, the Cossatot and Rolling fork. The soil of this region is usually barren, and the forest trees of but moderate size.

The tract lying south of this and based on later formations is less hilly, less stony, and more fertile. The soil has usually resulted from the disintegration, *in situ*, of clays, marls, limestones and soft sandstones. They vary greatly in productiveness; in some localities generous crops are produced; in others the soil is thin and soon exhausted. The well known "black lands" furnish a deep, productive and inexhaustible soil, while there are fine farming tracts along many of the rivers.

The streams of this portion are more sluggish, and often the flood plains are wide, swampy and subject to overflow. Examples of such flood plains may be found along the Terre Noir and Little Missouri below Murfreesboro. The vegetation is also more luxuriant than in the hilly region further north. The greater part of the country is covered with a heavy growth of yellow pine, which is in places being rapidly converted into lumber. The broad river bottoms also support a growth of evergreen and deciduous trees that are remarkable for their number, size, and excellent quality of their wood.

The Mesozoic Border Across Clark County.—The most northern point along the western bank of the Ouachita river where cretaceous deposits are now known to occur is on the west bank, and near the mouth of the De Roche creek, close to the line between sections 21 and 22. Here, just before the creek enters the Ouachita river, is exposed a bed of lignite that varies in thickness from two to three or more feet. It is a solid bed, but is much weathered where exposed, and is so full of iron pyrites and copperas that it will not burn. Above this bed of lignite there is a layer of sand, and this is overlain

by gravel and clay, probably post-tertiary. Beneath the lignite there is another bed of sand at least twelve feet in thickness, as shown by an excavation that has been made in it by persons searching for valuable minerals. Immediately south of this exposure of lignite, and within twenty feet of it, there is an outcrop of paleozoic quartzite, having a dip of 48° south, 10° east. As the bluff of the creek is followed northward, there comes into view, within perhaps twenty rods, a hard clay shale having also a high angle of dip to the south, and a little further on another layer of quartzite. The lignite, and the sands above and below it seem, therefore, to lie in a kind of a pocket or cove in the paleozoic rocks.

How far the mesozoic deposits in this cove may extend toward the west cannot be determined on account of the thick layer of post-tertiary gravels and clays that overlies it.*

Below the mouth of De Roche creek, in a few places along the western bluff of the Ouachita river, before Caddo creek is reached, there is found a hard siliceous limestone. Usually the pieces lie in the talus of the bluff; but within 200 yards of the mouth of the Caddo the rock appears to be *in situ*. In any case the stratum cannot be far from the surface.

Further down the Ouachita in section 8, 7 S., 19 W., where the river makes an abrupt turn from flowing in a westerly course to a direction east of south, there is a long and high bluff known as the "High bluff," which gives an admirable section of the mesozoic deposits of this region. Accurate descriptions of this section and of its numerous fossils appear elsewhere. West of the mouth of the De Roche it was found impossible to determine the exact northern limit of the mesozoic rocks, a great amount of post-tertiary materials having been heaped upon both the paleozoic and the mesozoic rocks. In the western half of township 6 S., 19 W., no actual outcrop

*A good deal of labor has been expended at this locality in the hope of obtaining gold and other precious metals from the iron pyrites which is so abundant above and through the lignite. It is improbable that the locality will yield anything of value.

of the paleozoic quartzites were found further south than section 8, 6 S., 19 W., where the dip is 48° S., 10° E.

The country north of the Caddo is everywhere very rough and stony, and it seems very probable that the paleozoic extends further south than is indicated at the surface. For the present the "military road" may perhaps be taken as following the boundary between the two formations from section 21 to where the road crosses the Caddo in section 30. From this point the line probably follows the Caddo, since south of this a short distance, probably on the north side of section 6, 7 S., 20 W., numerous cretaceous shells were found in the blue clay that had been thrown out of a well some twenty-five feet deep. Further west along the military road, close to the eastern side of section 2, 7 S., 20 W., in a ravine over which the road crosses, is seen an arenaceous clay in which occur occasional internal casts of shells. The soil in the vicinity is usually free from gravel, and is supposed to be of cretaceous origin, although it may here and there be overlain by post-tertiary materials. It appears probable that the cretaceous extends northward into the angle formed in the southwestern corner of 6 S., 20 W., between the Caddo and the Big De Gray creek, but no farther, since at the mouth of the Big De Gray there is a heavy outcrop of the paleozoic strata.

Further up the Big De Gray on section 35, 6 S., 20 W., and just north of W. M. Jones' house, the creek runs over a hard quartzite in layers that are nearly horizontal, or that dip slightly toward the south. A quarter of a mile further north on the Little De Gray, the same rocks are found to have a dip of 28° S., 10° E.

From the last named point on the Big De Gray, half way to the military road, the soil contains much coarse gravel and cobblestones, and no evidence could be discovered of mesozoic rocks having been reached in wells. Further south the soil becomes finer, and at length, just south of the military road, on section 2, 7 S., 20 W., slabs of a hard siliceous limestone occur on the hillsides. These do not appear to contain fossils, but numerous fossil spiral shells, probably some species

of *Turritella*, are said to be found near this place. On section 12 along Mill creek or one of its branches, was found a bluff some twenty feet high which gave the following section:

SECTION.

Soil and weathered rock.....	2 feet.
Impure limestone.....	4 feet.
Shales with nodules of impure limestone without fossils.	14 feet.
Total	20 feet.

The trend of the face of the bluff is N. 70° E., and the strata have an evident dip of from 5° to 10° toward the south.

All the country lying between section 2, 7 S., 20 W., and Arkadelphia is based on cretaceous deposits, and usually these deposits form the surface soils; but occasionally they are overlain by gravels and clays of later date which are more abundant near Arkadelphia.

On the west side of section 14, 7 S., 20 W., in a gully leading to the Little Deciper, is an exposure of about two feet of blue clay, and over this six or eight feet of red and gravelly clay. In the blue clay were found fossil oysters and pieces of gypsum. A similar exposure is seen on the east half of section 16, where in the pebbly blue clay are specimens of *Ostrea* and *Exogyra*.

Striking the Big De Gray again about the center of section 3, 7 S., 20 W., it is found to have wide, timbered "bottoms." Along the higher ground bounding this flood plain on the south runs the military road. Wells along this road and in this section have penetrated the cretaceous deposits, and specimens of the shells were shown me. On the southwest quarter of the section is a very interesting locality, in the bed of the Big De Gray. Here are to be seen the remains of a number of fossil trees, some of whose trunks are from ten to eighteen inches in diameter and several feet in length. They occur for eight or ten rods along the stream, partially buried in a soft yellow sandstone which is itself overlain by cemented gravel. These fossil logs and branches are sandstone casts, consisting of a hard outer crust and an interior filling of soft

sandstone. It seems quite probable that they are of cretaceous age; and if so, these deposits must extend for some distance north of the Big De Gray. The character of the soil for a mile or more toward section 33, 6 S., 20 W., gives countenance to this theory.

On the north side of the northwest quarter of section 33, 6 S., 20 W., occurs a brown siliceous paleozoic rock, dipping south 2° east at an angle of 22° . This rock is said to be easily worked when first taken from the quarry and to harden upon exposure. Another sandstone that is found on the same section is still softer when quarried, so that it can be hewn with an axe; and yet on exposure it becomes sufficiently hard to be used for grindstones. On section 14 of the same township, is found a coarse grit which has been successfully used for millstones.

On the northwest quarter of section 10, 7 S., 20 W., a well penetrates, at seventeen feet, a hard siliceous limestone containing a few cretaceous shells.

On the northwest quarter of section 5, 7 S., 20 W., near the line between this section and the one just north of it, on the north bank of a ravine crossed by the "De Gray road" and about two rods from this road, is an exposure of mesozoic deposits. At the bottom are two feet of sandy, blue clay which contains a few shells, and this is succeeded above by about ten feet of a fine white sand mottled with rusty spots. About seventy-five yards southwest of this a spring breaks forth from a ferruginous sandstone the age of which could not be determined. A large mass of paleozoic quartzite, possibly merely a large boulder, lies near this spring. North of this, however, a quarter of a mile or less, where the road crosses the Big De Gray, there are extensive paleozoic outcrops. The dip of these tilted strata was taken in two places near each other.

LOCATION.	DIP.	DIRECTION.
S. E. quarter of section 5, 7 S., 20 W.	45°	N. 28° W.
S. E. quarter of section 5, 7 S., 20 W.	40°	N. 20° W.

This hard sandstone was traced west of the road about one-eighth, and east of it one-fourth of a mile; and everywhere it had about the same dip.

Further west along the military road, on the line between sections 7 and 18 of 7 S., 20 W., and near the eastern line of these sections, along the head of the Big Deciper, was found a blue clay that contained many fossils, among them many specimens of *Exogyra costata*, some of them with the two valves in their original positions. The cretaceous clays could be traced for many yards up the hillsides. The soil here on the high grounds is a red clay, sometimes containing gravel, sometimes without it. In the latter case, at least, it seems to be of cretaceous origin.

It is probable that in the western part of this township the Big De Gray forms the northern boundary of the cretaceous. On the northwest corner of section 8, a limestone was found containing cretaceous shells, and underlain by a clay having in it spots of calcareous matter. Again, on the southeast quarter of section 1, 7 S., 21 W., on the land of C. B. McCauley, was found in a ravine some rods north of his house, a detached block of hard limestone that was almost wholly composed of fossil shells both entire and broken. It was no doubt derived from a stratum now hidden in the soil of the hillside. A short distance away from this spot but on the northwest corner of section 7, 7 S., 20 W., several outcrops of a siliceous limestone occur in ravines that open toward the Big De Gray. In one exposure, at least six feet of this limestone is shown, and it seems to be resting on a bed of soft sandstone that weathers into a fine sand. A quarter of a mile northeast of these localities at the crossing of the county road, the bed of the Big De Gray is composed of lower carboniferous shales, having a strike S. 70° W. and a high dip to the south. On account of the weathered condition of these shales the amount of the dip could not be satisfactorily measured. Four or five miles further up the stream its bed was composed of alternating layers of shale and metamorphosed sandstone standing nearly perpendicular, while the beds still farther north have a dip to-

ward the north ; and still higher up the creek, on the east half of section 1, 7 S., 21 W., the north dips continue. An outcrop of a hard paleozoic sandstone in the northwest quarter of section 1, 7 S., 21 W. crosses the road leading from Arkadelphia to Alpine. Further toward the northwest, probably on the west half of section 35, 6 S., 21 W., on what is known as the Freeman place, a very fine grained and soft sandstone was found, which had just been thrown out of a well, and which contained the casts of a number of marine gasteropod and lamelli-branch shells. It was further learned that limestone containing shells had been taken from their wells by several persons living on the section immediately south of the one just named. West of these sections Briar creek and Winfield creek flow over paleozoic deposits, and there is said to be a high bluff of paleozoic sandstone along Winfield creek about the center of section 15, 7 S., 21 W. There seems, therefore, to be a tongue of the cretaceous running up between the Big De Gray on the east and Briar and Winfield creeks on the west, and this extends as far north as the southwest quarter of section 35, 6 S., 21 W. From its most northern point the mesozoic border descends east of the creek just named, to the vicinity of Hollywood.

South of Hollywood are numerous cretaceous outcrops on both sides of Bradshaw's creek, while the surface soils appear to have been derived from rocks of the same age. On the northeast corner of section 13, 7 S., 21 W., along the military road as it descends toward Bradshaw's creek from the east is found an exposure of twelve feet of sandy clay, yellow and blue, mixed with a good many pebbles and cobblestones ; and in this were found the remains of fragile shells. All the country lying between Winfield and Bradshaw's creek, and south of the military road, is cretaceous. It is high, in places quite broken ; elsewhere level, and well wooded with deciduous trees. Usually there is little or no gravel, and this little is superficial. On sections 34 and 35 are numerous "limestone points," where a soft limestone has been denuded of its overlying soil ; and on these "points" are to be found many speci-

mens of *Exogyra* and other cretaceous fossils. The water of the wells dug in the limestone is too strongly charged with calcareous, and, perhaps, other salts, for domestic use, and resort is had to cisterns.

At the road crossing the Terre Noir, on the north side of section 24, 8 S., 24 W., the river bank shows a lower stratum of tough, mottled, blue clay eight feet thick, and an upper stratum of seven feet of sandy clay. Further east along the southeastern bluff of Bradshaw's, near the east side of section 13, is a good section of cretaceous deposits, the estimated thicknesses of whose strata are given below :

SECTION.

Yellow and orange clay, forming the surface soil.....	10 feet
Fine sandy clay, with calcareous concretions.....	15 feet
Soft or "rotten" limestone to the base of the hill.....	15 feet
Total.....	40 feet

The limestone, where exposed on the hills near this locality, contains abundant fossil oysters, cephalopods and echinoids. One specimen of *Nautilus* was found that had a diameter of about one foot. The intermediate stratum of the section given above contains near its upper part a layer of large concretions of impure limestone, some of which were three feet long and a foot thick.

Returning to the vicinity of Hollywood we find that north of the town the interval between Winfield creek on the east and its tributary, Mill creek, on the west, is either rocky or covered with clay and coarse gravel. Along the bed of Mill creek on the north half of section 21, 7 S., 21 W., are outcrops of the paleozoic rocks. Near John House's place the shale has a dip of 73° , N. 20° E., and its joints a strike of N. 68° E. About 150 yards further down the creek is a metamorphosed sandstone having a dip of 67° , S. 10° W. No satisfactory outcrops of the strata were found between these two points. Some three-quarters of a mile below this the dip was 66° , S. 15° W. Here the hard metamorphosed sandstone is jointed,

the fissures dipping 50° , S. 50° E., and the thickness of the rock exposed is probably twenty-five feet. This formation, with about the same amount and direction of dip, continues to near the south line of section 21.

No satisfactory evidences were obtained of the existence of cretaceous deposits nearer Hollywood than the points here recorded. Northwest of the town along the road to Alpine, for nearly a mile, the soil and the topography of the country give one the impression that the deposits are mesozoic; but this does not continue far. About a mile from the town what is evidently an outcrop of the paleozoic crosses the road, and soon the country becomes very hilly, and exposures of paleozoic quartzites are common. On section 20 (probably the south half), along a ravine opening into Bell's creek, is an exposure consisting of unaltered soft sandstone and shales tilted at an angle of about 45° toward the south. Thus no cretaceous was found north of the military road, and between Mill creek and Bell's creek, but about one-eighth of a mile south of the road, on the northwest quarter of section 32, the earth thrown from a well at a depth of about twenty-five feet contained numerous cretaceous fossil shells. It is probable, therefore, that the cretaceous does extend north of this road, perhaps for a mile. At the crossing of Bell's creek is another outcrop of the metamorphosed sandstone. It continues down stream for several rods, but south of this it does not appear again. On account of the fissured and weathered condition of the rock its dip could not be satisfactorily determined.

The country between Bell's creek and the Terre Noir is approximately level, and not so elevated as that east of Bell's creek, appearing to be a sort of elevated flood plain. It is covered with a thick deposit of clay, gravel and some conglomerate. On the east bank of the Terre Noir, where it is crossed by the military road, this conglomerate is about twenty feet thick, and the soil in the vicinity contains large blocks of paleozoic sandstones. Above the crossing, one-eighth of a mile or less, a gully shows the order of the strata forming the

hills. The section exposed is about twenty-four feet, as follows:

SECTION.

1. Loose earth and gravel.....	7 feet
2. Friable sandstone in layers from two inches to one foot thick.....	4 feet
3. Loose sand and gravel and a thin layer of clay.....	1 foot
4. Soft sandstone.....	12 feet
Total.....	24 feet

These beds dip south at an angle of about 5° . No fossils were discovered in these strata, but some of them are doubtless of post-tertiary age, while the lower sandstones are probably cretaceous. A few rods further up the stream is an outcrop of paleozoic rocks. West of the Terre Noir, on the northeast quarter of section 36, 7 S., 22 W., a well has been dug in very coarse gravel, but no mesozoic rocks seem to have been reached. A resident, however, told me that a quarter of a mile further south large shells, probably of *Exogyra costata*, were found at a depth of twelve feet from the surface.

The first outcrop of the paleozoic rocks west of the Terre Noir occurs along a branch of Moore's creek, in section 26, 7 S., 22 W. Here the flat face of the hard sandstone stands up along the roadside some seven or eight feet high, with a dip of 47° , S. 12° W. No direct evidences were found in the southeast corner of the township of the occurrence of cretaceous deposits north of the military road, but it is probable that they extend northward close to the last described outcrop of the older rocks. West of the crossing over Moore's creek, on the west side of section 3, 8 S., 22 W., high up on a hillside, was found a "joint clay" containing shells of *Exogyra*. From this point to Clear Springs the mesozoic rocks come up close to the township line, and lie in close proximity to outcrops of the paleozoic. Near Mr. Turner's, on section 4, along the military road, were found numerous specimens of *Exogyra costata* and other fossils; and a thin layer of limestone containing many other fossils is also exposed. A quarter of a mile north

of this there is an outcrop of post-tertiary conglomerate. Wells along the military road on sections 4 and 5 reach, at a depth of from ten to eighteen feet, a hard, blue, calcareous clay that contains numerous marine shells. This clay serves to retain the water that comes in from above, but such water usually contains sufficient organic matter in solution to make it unwholesome. In digging a well on the east half of section 4 Mr. Turner went through this clay at a depth of forty feet, reaching gravel and sand, and obtaining an unfailing supply of water. It contains, however, in solution, mineral salts, probably of iron. The "joint clay"* overlying the blue calcareous clay requires to be supported by casing in order to prevent it from falling into the well.

Paleozoic grits crop out about one-quarter of a mile north of the military road, and are exposed in the wells that have been mentioned.

Near the southern line of section 32, 7 S., 22 W., measurements of the dip were taken which show that it was about 45° , S. 15° W. Southeast of this locality, probably on the northeast corner of section 5, 8 S., 22 W., there is found a fissile sandstone highly colored with iron; it is soft, but said to harden upon exposure; the dip is 53° , S. 10° W.

Immediately west of Clear Springs village the mesozoic border bends abruptly toward the south, being limited on the west by paleozoic outcrops. One of these outcrops occurs along the Little Antoine on the northwest quarter of section 7, 8 S., 22 W. Another occurs near the northeast corner of section 18 of the same township, where the dip is 50° S., 4° W. About a quarter of a mile southwest of this, on the northeast quarter of section 13, 8 S., 23 W., close to the east line of the section, the dip is 70° due south. There are irregular masses of unchanged clay in the metamorphosed sandstone at this place. On the northeast quarter of section 18, 8 S., 22 W., is

*"Joint clay" derives its popular name from the manner in which it breaks into angular lumps when dry or exposed to atmospheric influences. This characteristic is not confined to any particular bed of clay, but any clay which breaks in this manner is called "joint clay."

a heavy outcrop of conglomerate. Further east, but still on section 18, near the Methodist chapel, are several springs, some of which have a feeble taste of minerals. They escape from beneath a low ledge of sandstone that has considerable dip toward the south. Beneath this sandstone is a thin bed of bluish sand, while above it is a layer of clay a foot thick which resembles "joint clay." No fossils were found in any of these layers, so that their age could not be determined, but it seems probable that some of them, the clay at least, are cretaceous.

The mesozoic border may be regarded as running southward along, or close to, the eastern side of the Little Antoine creek to about section 30, where it probably turns west across the Antoine.

The region southwest of the Terre Noir creek was examined as far south as Dobyville and Okolona. All this country is based on cretaceous deposits, but is drained by numerous streams tributary to the Terre Noir, each of which has "bottoms" of alluvial origin of greater or less width. In addition to these there is about Dobyville a considerable area of what is known as "black land." These alluvial deposits and "black lands" overlie and obscure more or less completely the cretaceous rocks. The "bottoms" have a dense forest growth, especially of sweet gum, black gum, and sycamore, while the higher lands support a fine growth of white, post, and red oak, with some pine.

About Dobyville cretaceous exposures are common. The hills north and west of the town, on sections 28, 29 and 30, have been, to a considerable extent, denuded of their original covering of soil, and the "rotten limestone" is now exposed. On these hills may be gathered an abundance of fossils, among which *Exogyra* and *Gryphæa* are most conspicuous. These fossils were formerly largely used for making lime. South of Dobyville, on the line between 28 and 33, is an outcrop of solid limestone, which has been used for foundation walls and for the making of lime. In this limestone are numerous cylindrical, more or less curved columns, or rods, about half an inch in diameter, descending perpendicularly through the limestone

sometimes to a depth of a foot. They seem to be the filling of worm holes. Pieces of such columns are frequently found lying about on the denuded limestone hills.

North of Dobyville is a considerable tract of the "black lands," sections 15, 16, 20, 21, 22 and 28 being either wholly or to a great extent covered by it. This soil is fine and black, and in places of great depth. It usually occupies a lower level than the surrounding country, but around the edges of the basins it extends far up on the sides of the cretaceous hills, and covers them with a thin layer, which, mixed with the calcareous materials, adds greatly to the fertility of the farms. This enriching soil is, of course, constantly being washed down from higher levels, and often the only evidence that it was ever there is the characteristic shells that are found scattered about on the undisturbed surfaces. Geologically this soil is of very recent origin, many of the contained shells retaining the pattern of their coloration.

No deposits of this black soil were found in the northwestern corner of township 8 S., 21 W., but in its stead are found red clays extending up to the bottom lands of the Terre Noir and Moore's creek. West of Dobyville the washed and bare limestone hills extend south of and parallel with Love creek to about section 28. Love creek itself, for a part of its course, at least, flows in a cretaceous channel. Along this creek about two miles north of Okolona is exposed an abrupt bank consisting of about eighteen feet of "joint clay," with a narrow interrupted band of limestone running through it about six feet from the top.

In the vicinity of Okolona, after passing through the superficial red clay, a hard "blue rock," or "black rock" is reached in which cisterns are excavated. This rock appears to be simply a very compact calcareous clay, which on exposure to the atmosphere soon disintegrates. In some blocks of this rock thrown up from a cistern in Okolona, I found numerous specimens of a species of *Baculites*. This rock has been used for lining fireplaces, and is said to last for many years. It is quite probable that some of these deposits have the calcareous and

argillaceous materials in the proper proportion to make a good hydraulic lime. Col. Ross of Okolona informed me that it has been ground and used to make a mortar for spreading on hearths, and that it hardens and lasts indefinitely. On higher lands the red clay overlying it is said to be but a few feet deep, while in the valleys between the hills the thickness may be as great as thirty feet. Furthermore no fossils are found in the red clay. When not of post-tertiary origin, as little of the red clay about Okolona seems to be, it has come from the disintegration of the cretaceous deposits; probably much of it from the breaking down of the "blue rock." Rainwater charged with carbonic dioxide and percolating slowly through the rock has dissolved the cementing carbonate of lime, and left the argillaceous materials that now form "joint clay," while the removal of carbonate of lime has produced shrinkage and division of the clay by its characteristic joints. Nearer the surface it has been more thoroughly disintegrated by the action of rain, atmosphere and frosts, and thus the loose surface soil has been produced. The differing colors of the "blue rock," the "joint clay" and the superficial soils, are due to the different chemical conditions of the included iron.

In the unchanged cretaceous deposits, the iron is in the condition of protoxide, or more commonly perhaps, as iron sulphide in the form of pyrite and marcasite. In such forms iron imparts little color to the rocks, and their dark color may be due to the presence of organic matter in it. Exposure of the iron to the oxygen of the air, as happens when the rock is disintegrated, leads to the formation of higher oxides, which have a yellow or red color. The iron sulphide becomes oxidized into the sulphate, which on reaching the carbonate of lime, leads to the formation of gypsum and carbonate of iron; and the latter may again be converted into red, sesqui-oxide of iron. Such abundant red compounds of iron impart their color to the soils. The absence of fossils in the upper red clays and usually also in the "joint clay" is to be attributed to their having been dissolved out by percolating waters. The more massive shells, as *Exogyra* and *Gryphæa* may resist this

action longer, but the smaller and more delicate species soon disappear. It is not uncommon, however, even in the loose clays, to find the clay casts of the smaller shells.

One mile northwest of Okolona the following section was obtained in boring an artesian well :

SECTION.

Red clay	8 feet.
"Joint clay"	12 "
"Black rock "	70 "
Total	90 feet.

In the vicinity of Okolona there is a good deal of "black land," especially southwest of the village, but patches of it are found north of the town and these sometimes extend high up on the hills.

The Mesozoic Border Across Pike County.—As the Antoine "bottoms" are approached the red clay becomes coarse and gravelly. Paleozoic rocks outcrop abundantly in the vicinity of Antoine, where they occur in beds of such thickness that they can be readily quarried. They are much used in the construction of chimneys, for which purpose they appear to be admirably adapted. Below the village outcrops of these quartzites were followed down the Antoine river to near the middle of section 24, below which point the valley seems to be entirely of alluvium. The flood plain is broad and heavily wooded, and where cultivated produces generous crops of corn and cotton. At the crossing of the road leading to Clear Spring the paleozoic presents itself as a soft greenish sandstone. Similar outcrops occur along the military road nearly to Clear Spring village.

Northwest of Antoine, probably on the south half of section 15, along a little rivulet known as Suck creek, hard sandstones and shales with a high south dip were observed. At one point this dip amounts to as much as 50° , S. 20° W., at another 36° , S. 30° W. One-half a mile further to the northwest nearly vertical shales cross the stream with a strike nearly east and west. One hundred yards from the last named

place the dip is 75° , N. 14° E., the strata thus showing in this limited area a reversal dip.

About one-quarter of a mile southwest of Antoine on the road leading to Murfreesboro, is an outcrop of post-tertiary conglomerate, while west of the town, probably on section 21, a well is reported to have been dug thirty-five feet in coarse gravel and cobblestone, also, doubtless, of post-tertiary age.

West of Antoine creek, its tributary, Wolf creek, appears to form for many miles the northern limit of the mesozoic deposits. These are first met with on the south half of section 26, one-fourth of a mile south of Wolf creek, along the military road, where many specimens of *Exogyra* occur. Wolf creek has a bed of coarse gravel, and its broad flood plain has a good deal of gravel and stones scattered over it, showing that it is subject to strong freshets. Further back from the stream the bottoms, in some localities, furnish excellent lands, and are partially composed of the "black land" soil, which extends back for some distance on the hills.

On a farm near the northeast corner of section 29, are outcrops of a thick bedded and solid, but apparently unmetamorphosed, sandstone, having a south dip of from 10° to 15° . Other outcrops occur both east and west of this; one near the east line of the section showing a fissile sandstone having apparently a dip of 15° to the south. This appearance may, however, be due to false bedding. Overlying this is an ash colored clay, while a few yards further up the hill are numerous specimens of *Exogyra costata*. It seems probable that the sandstone just referred to is also mesozoic. About one-fourth of a mile east of the last point mentioned, along a branch that flows into Wolf creek, there is exposed a bluff of sandstone some fifteen feet high. Under the hammer it breaks readily into sand. The bluff faces the west, and the planes of stratification seem to show a slight dip to the south. There is a tract of "black land" on section 29. At the house of Mr. Wilson, on the northeast quarter of section 29, a well bored to the depth of 138 feet, has the upper thirty-eight feet in red

clay, and the remainder in dark colored shales or calcareous clays.

Somewhere between sections 29 and 14, 8 S., 24 W., the northern border of the mesozoic crosses to the north side of Wolf creek. This point may be as far west as the last named section. The first indications of its presence north of the stream are along the east side of Dry Branch, a ravine draining southward through sections 2, 11, and 14. West of this branch, and lying between it and Wolf creek is a high limestone ridge that extends north as far, at least, as the southern line of sections 2 and 3, and south to section 15. The limestone which crops out high upon the hills is very hard, filled with the shells of a small species of oyster, and in places comes out in blocks a foot thick. It was formerly employed for making lime.

On the south half of section 3 along Wolf creek are paleozoic outcrops which run directly across the bed of the creek, and dip 56° S. 14° E. The most southern outcrop of this formation at this point is about opposite the most northern appearance of the limestone on each side of the creek. On the west half of section 3, and on the south side of a branch of Wolf creek, is an exposure of limestone ten feet thick, hard and filled with oyster shells, while beneath this is a bed of blue clay which becomes red on weathering. From this vicinity west to Ultima Thule, the northern edge of the cretaceous, wherever seen, is represented by a hard ringed limestone usually filled with specimens of the genus *Ostrea* and devoid of specimens of *Exogyra*. This limestone has since been recognized by Mr. Hill as belonging to a formation occurring in Indian Territory and Texas and called by him the Trinity formation.

On the east bank of Wolf creek, on section 10, near the school-house, is an exposure of about eight feet of conglomerate. Further up the hill is a bed of limestone. Not far from this, but on the west side of the creek, there is a hill probably eighty feet high capped by a heavy deposit of puddingstone. In places this puddingstone forms abrupt faces twelve or fifteen

feet high. The beds are horizontal, the lower and more yielding ones upon being disintegrated leaving the upper and more thoroughly consolidated beds as projecting shelves. The materials consist of siliceous stones from small gravel up to the size of one's fist or larger.

In the southeast corner of section 4 a boring was made some years ago in the expectation of finding oil. Within ten feet of the surface a black substance was struck which resembled coal in appearance, and which burned readily when ignited. The boring was continued about sixty feet, at which depth a hard rock was struck, and work discontinued. Afterward Mr. J. A. Craighead, of Wolf Creek Post-office, and others dug into the black deposit some ten feet. This opening was filled up at the time of the writer's visit, but lumps of the supposed coal were found lying about on the surface. They appeared to consist of grains of fine sand held together by asphaltum, and although they have been exposed to the atmosphere for some eight years, these lumps are still soft and spongy.

On account of the alluvial deposits which obscure the underlying rocks it is impossible to say just where the mesozoic border crosses Saline creek. It is said, however, that ledges of limestone are found in the bed of this stream about a mile south of the Murfreesboro road, while other strata may be buried under the alluvium farther up the creek. West of the Saline the border appears to run northwest parallel with the Murfreesboro road, and about one-half a mile north of it until it strikes the head of Spring creek on the north half of section 2, 8 S., 25 W. Along the south side of this creek it runs toward the southwest, forming an escarpment, along the top of which runs the Murfreesboro road. In the rather narrow interval between the mesozoic border and the underlying paleozoic strata the land is usually rather low and flat, and covered with a soil that contains rounded cobblestones and masses of conglomerate. At many points between Brockton and Murfreesboro are outcropping ledges of limestone; at other points limestone slabs lying loose in the soil of cultivated fields indicate the presence beneath it of strata of similar material. In

many places the soil shows great fertility, even where it is encumbered with great quantities of limestone fragments. This limestone stratum is probably as much as twenty feet thick, and, judging from its outcrop in the hillside, it may be even much thicker. It is underlain by a blue shaly clay, which weathers red, and is overlain in many places by a mixture of clay, waterworn material and conglomerate. Often perfect shells from the limestone are weathered out in great numbers.

Paleozoic strata outcrop along Prairie creek near the line between sections 4 and 5, about two miles from Murfreesboro. Further down the creek the channel is filled with the small and large blocks of hard paleozoic quartzite.

West of Prairie creek the cretaceous border appears to sweep northward through the middle of section 8 and on to section 5, where it turns westward again. Fossiliferous limestone is found on the land of Moses Robinson, in the northeast quarter of section 8, along the hillside facing Prairie creek. A half a mile or less north of this, along the Kirby, or Cheny Trace, road, is a heavy outcrop of paleozoic rocks dipping from 60° to 64° from 20° to 28° east of south.

After crossing the Clear fork of the Little Missouri the mesozoic border bears northwest into section 36, 7 S., 26 W., where it is found on the land of Thomas Kidd, in the southwest quarter of the southeast quarter of section 36. Here also hard paleozoic sandstones occur, having a dip of 67° , S. 8° E. The limestone occurs upon the surface within a hundred yards of the sandstone, and it was also struck in a well fifteen feet deep, located within fifty yards of the sandstone. From Mr. Kidd's place the mesozoic rocks continue to the northwest into the northwest quarter of section 36, thence southward toward section 35, thence south into section 2 of the township just south. On Mr. Farley's farm, in the southwest quarter of the northeast quarter of section 2, a small branch separates the mesozoic and the paleozoic formations. Going south from Farley's one suddenly comes upon a paleozoic outcrop, and again a little farther south the mesozoic is encountered.

The outcrop of the older formation just referred to may be followed eastward for some distance, probably to about the west side of section 1, and it appears to have been a sort of rocky headland reaching out into a bay of the mesozoic sea. The margin runs along the south side of this spur to the flood plain of the Muddy fork. Just north of its edge and east of Muddy fork is another ridge of paleozoic quartzite. On the west bank of Muddy fork, where the road running to Nathan crosses it, probably on the southwest corner of section 2, slabs of mesozoic limestone are found near Mrs. Westerman's house, on the northwest quarter of the southwest quarter of section 3. The relations of the older and the newer rocks here are quite interesting. The paleozoic outcrop forms a high ridge composed of large boulder-like masses that have resulted from the weathering of the rock; and so confusedly are these piled together that it is with difficulty that the dip can be determined. This was found to be 53° , S. 30° E. This ridge may be followed west from this point nearly or quite to Bacon's creek. On the west side of section 4 there is little doubt that the continuation of the same ridge eastward is found in the ridge just east of Muddy fork, and in the outcrop about the middle of section 5, 8 S., 25 W., and also in the outcrop in section 4 along Prairie creek.

In section 3, near Mrs. Westerman's house above referred to, the mesozoic limestone runs up within one hundred yards of the south side of the ridge just described, and no doubt, could the surface accumulation be removed, the limestone would be found lying unconformably against the quartzites. It follows closely the south side of this ridge west to Bacon's creek, and then continues northwest to near Muddy fork on section 32, 7 S., 26 W. On Bacon's creek the limestone is in layers six inches or more in thickness, and is filled with fossils. It is extensively used for building chimneys. Dr. Owen (Second Report, p. 126) states that there are some fifty or sixty feet of solid cretaceous limestone along Bacon's creek. Along this creek, on section 8, is also found a stratum containing lignite. Dr. Owen (loc. cit.) states that the bed is three feet thick,

but all that was found on a visit to the locality was a stratum of clay shale three or four feet thick, containing here and there the altered trunks of trees. There is no considerable amount of coal, and what there is contains so much iron pyrites that it would not make good fuel. There is also much iron pyrites found in the clay in which the fossilized wood is buried. Copperas springs are reported at many points, such springs doubtless deriving their copperas from the oxydized pyrites so abundant everywhere in the mesozoic clays and shales. Lignite beds are reported at points further west, and also on Wolf creek, but they were not visited.

The Mesozoic Border Across Howard County.—Further down Bacon's creek on the south half of section 33, 7 S., 26 W., is another heavy outcrop of the quartzite. This forms a ridge which runs north of, and parallel with, the one last mentioned. Where the road running north from Wilton crosses Muddy fork creek (which point is probably just north of Nathan, or possibly a little further east), there is along the west side of the creek a fine display of folded paleozoic sandstones and shales, the same strata being folded some five or six times within a distance of three or four rods. The most conspicuous stratum is one of hard sandstone fifteen inches in thickness, and this is bent three or four times at a right angle, and at one point it is bent back so as to make a very acute angle, although the apex of the angle in this case is hidden from view.

Immediately east of Nathan Post-office, which is on the northeast half of section 31, the paleozoic rocks are exposed along a ravine about a fourth of a mile north of the road, while mesozoic rocks are found about the same distance south of it. At the Muddy fork crossing of the road leading from Nathan to Muddy Fork Post-office, is a fine section of post-tertiary sands, conglomerates and gravels, resting unconformably on the tilted paleozoic sandstones and shales. The faces of the latter are also exposed in the bed of the creek, and within a few rods show a reversal of dip. At one point the dip is 65° , N. 27° W., while two rods up the stream the dip

changes to 78° , S. 27° E. Between these points it varies, some of the strata being perpendicular. The bluff of overlying gravel and sand is on the north side of the creek and rises to the height of about forty feet. The bedding is horizontal or nearly so, and the materials are mostly gravel, some quite coarse, and much of it cemented into a puddingstone. Through this and about six feet from the bottom of the section, runs a bed of fine white friable sandstone about one foot thick. The upper end of the section rests unconformably on the upturned paleozoic beds. Near this locality the mesozoic margin crosses to the north side of Muddy fork, but the overlying post-tertiary material is so thick that the exact place cannot be determined. The border probably passes along the west side of section 25 to the north side of section 26, where it runs about due west to section 20, where it again crosses the Muddy fork. It is, however, not known to occur quite so far north as has just been indicated. Limestone is found at several points along the road from the crossing over Muddy fork, from section 36 to section 20. Some of these points are probably on the south half of section 26, and others are on section 27. There appears to be about twenty feet of this limestone, and the individual layers are sometimes a foot thick. Mr. Price, on section 28, reports limestone in the soil of his farm. Limestone was also struck in a well here at the depth of eighteen feet, while half a mile north of this is an outcrop of paleozoic rocks.

On section 34, or near it, on the north side of the narrow flood plain of the Muddy fork, is a fine exposure of mesozoic limestone in a high hill, which seems to be wholly composed of it. On the other side of the creek, but a little further up the stream, the bank is composed of about twelve feet of limestone, having a dip of about 5° to the south. The limestone is underlain by a bed of very fine bluish sand.

Numerous observations were made on the paleozoic and mesozoic formations on section 20, near the residence of Dr. B. F. Jones. North of his house along the Centre Point and Caddo Gap road, an outcrop of hard quartzite is found having

a dip of about 70° N., 14° W. This ridge was traced east of the road about a quarter of a mile and as far west of it. It probably continues farther in both directions. At the distance given west of the road, and on another ridge lying south of the preceding, the dip was about 50° N., 45° W. Both these ridges extend to the Muddy fork. A little west of north of Dr. Jones's house the outcropping edges of the paleozoic sandstones cross the creek, forming dams. At one point the dip is 86° N., 25° W., and a rod south of this it is reversed to 88° S., 32° E. These strata, having the same strike and a high angle of dip, are exposed for about fifty rods.

On the hill forming the west bank of Muddy fork creek, about due west of Dr. Jones's house and somewhat further north than the most southern outcrop of the paleozoic, thick beds of mesozoic limestones are exposed. They occur also on the middle of section 19, and on section 23, 7 S., 28 W. From the latter section the border runs off southwest, and passes out of the township through the southwest corner. Along the western portion of this corner it follows pretty closely the south bank of Holly creek.

The paleozoic strata are also found in the bed of Holly creek on section 29, west half of northeast quarter, where the dip is 79° S., 35° E. About a fourth of a mile further up the stream the strata become perpendicular or have a very high north dip.

Limestone is found along the south side of Holly creek on sections 32 and 31 of 7 S., 28 W., and on section 36 of the next township west. No limestone or other mesozoic rocks are known to occur north of Holly creek. This stream has a wide and densely wooded flood plain, and the trees are mostly of deciduous species. West of Holly creek the mesozoic reappears on the northwest corner of section 2, on the land of D. L. Weems. It is also reported as extending into the south side of section 35 of the township lying just north, but it was not seen there and certainly does not extend far into that section, as paleozoic outcrops occur not far away. From this point west to the West Saline river the hills are covered with

gravel and cobblestones, but it is probable that the mesozoic border follows pretty closely to the line between the townships, though hidden by post-tertiary deposits.

The Mesozoic Border Across Sevier County.—Near the north line of section 3, 8 S., 29 W., or possibly a little further north, paleozoic quartzites are seen crossing the bed of the West Saline, and dipping about 55° S., 40° E. West of the Saline, on section 3, and along what is known as the Fort Towson road, the soil is filled with coarse materials, among which are many boulders and blocks of quartzite that have been derived from the paleozoic deposits lying to the north. The most northerly outcrop of limestone along the west side of the Saline appears to be on the south half of the southeast quarter of section 4, on the land of David Allen, where it is abundant. It can scarcely be doubted, however, that beneath the superficial accumulations it extends further north, probably to the north line of section 4. It is next met with on the north half of the southeast quarter of section 5, on the lands of W. M. Burgess. Immediately north of this are the gravel-topped hills, which continue for some three-quarters of a mile north of the road. About the center of section 32, 7 S., 29 W., is a ridge of hard quartzite boulders which trends nearly southwest. This was followed for half a mile toward the west. On the northwest quarter of section 5, Mr. J. I. Kolb struck limestone in his well at a depth of eighteen feet. This well is close to the north line of the section, and on the north side of the Fort Towson road. From this place the mesozoic border probably follows this road closely, which here runs in a southwesterly direction, avoiding the outcropping paleozoic strata.

On the land of Kolb, northwest quarter of section 12, 8 S., 30 W., fossiliferous limestone was found in a well at a depth of fifteen feet. The hard paleozoic sandstone occurs a quarter of a mile north of this to the northwest corner of the section, forming a ridge, which is a part of that which occurs on section 32 of the township to the east, and the outcrop of quartzites in the bed of the Saline is probably still another part of it. As it is followed toward the west it bends more and more

toward the south, until on section 11, 8 S., 30 W., its trend is S. 15° W. On the last named section it is crossed by the Fort Towson road and may be followed to the south line of section 11, where it ends in a train of loose water-worn stones and gravel. Just south of the road on this section the dip is 55° , S. 75° E. Both north and south of the road on section 11 mesozoic limestone outcrops close against the southeastern flank of this spur, while the second flood plain of the Cossatot river extends against the western side and even around its southern end.

The "bottoms" of the Cossatot are here two or three miles wide, and heavily timbered where not cultivated. The soil appears to be very fertile. The greater portion of the flood plain is on the eastern side, while on the west the hills come close to the river. On these hills, probably on the southwest quarter of section 9, the mesozoic limestone was found in an old quarry. A little to the northeast of this, perhaps on the same quarter section, a ledge of quartzite having a dip to the north forms a dam across the river. The paleozoic rocks continue up the Cossatot on section 4, where they dip 37° , N., 30° E. Southwest of these localities for some distance there are, for the most part, high gravelly hills. At Dr. Smith's, probably on section 8, there is a hill on which are exposed ferruginous sandstone and conglomerate. Still further to the southwest on section 18, an exposure of from fifteen to eighteen feet of fine grained friable sandstone occurs along a ravine. On the hillside to the south the soil is black and seems to contain calcareous matter, while about a quarter of a mile further on, limestone crops out. The sandstone may be post-tertiary, but it is more likely of cretaceous age. A well dug on this section gives the following section:

SECTION.

Red clay	30 feet.
"Joint clay"	5 "
Sandstone	5 "
Total	40 feet.

East of this, on the west side of the southeast quarter of section 18, there is an outcrop of limestone, some of the beds of which are said to be two feet thick. Limestone is also found on the southeast quarter of section 13, 8 S., 31 W. The limestone of this region seems to be underlain by a stratum of sandstone. At one point a white sand underlies a siliceous limestone. On the southwest quarter of section 15 the limestone outcrops abundantly on the west side of a small ravine; while east of the ravine no limestone is found, although the hills are higher. Wells dug east of the ravine to a depth of fifty feet reach no limestone, but sand and sandstone. The thickness of the limestone and the sandstone make it probable that the mesozoic deposits extend further north than is indicated by the outcrops. This is rendered more probable by the fact that for a mile farther north the soil is fine and sandy. Beyond this the soil becomes gravelly, indicating the approach to the paleozoic. The mesozoic border is, therefore, in all probability, to be located along the south line of the second tier of sections in this township.

The Fort Towson road runs along the north half of the fourth tier of sections, and at many points along this road mesozoic limestone is exposed. It is usually hard and compact, ringing under the hammer, and filled with fossil oysters. Some of the beds are about six inches thick, although thicker strata could perhaps be found. As the Rolling Fork river is approached limestone glades become frequent. Here as elsewhere through the mesozoic regions, the presence of limestone may often be suspected from the presence of thickets of hawthorne (*Crataegus spathulata* Mx.).

East of the Rolling fork the last of the mesozoic north of the Fort Towson road is found near the line between sections 13 and 24, 8 S., 32 W. Here begins the flood plain of the Rolling fork, which has a width, east of the river, of about half a mile. This flood plain has a rich alluvial soil and where not under cultivation is heavily wooded with white oak and other deciduous trees. The mesozoic border probably runs along the border of the floodplain to Chapel Hill. On section

11 along the Rolling fork there is an almost perpendicular bluff sixty or eighty feet high, of hard metamorphosed sandstone, known as "Buzzard Roost." The dip of the strata here is S. E. 12° . Since the stream in this part of its course, runs nearly west as far as section 20, and along the line where the mesozoic border might be expected to occur, little more is seen of this formation between the river and the state line. Limestone is plentiful, however, on sections 19 and 30, while from 19 it continues west through 24 and into the Indian Territory. This limestone is used here in the construction of fireplaces and chimneys.

From section 15, 8 S., 32 W. the paleozoic continues west through sections 16, 17 and 18 and into section 24, 8 S., 33 W., just north of Ultima Thule. A half of a mile north of the town the dip of the outcrop is 22° , S. 24° E., while west of the town a few rods in Indian Territory, the dips taken were 14° , S. 30° E., and 19° , S. 35° E. It is not at all unlikely that the mesozoic border approaches Ultima Thule nearer than the south line of section 24, but close to the town. If there at all it is overlain by post-tertiary deposits.

CHAPTER XXIX.

ON THE MANUFACTURE OF PORTLAND CEMENT.*

By J. C. BRANNER.

Introduction.—The existence of extensive deposits of chalk in the region discussed in this volume of the report, and the interest of the people in these deposits render advisable a brief chapter upon the manufacture of Portland cement.

In discussing the processes employed in the manufacture of cement, no claim to originality is made. Mr. Henry Reid, an acknowledged authority on Portland cement, has written a valuable treatise on this subject, and free use has been made of his book. Indeed, wherever possible, Mr. Reid's words have been quoted, for, being a practical engineer

**Bibliography.*—The following is a list of works on Portland cement which may be of use to those desiring to investigate the subject :

Reid, Henry, C. E. The Science and Art of the Manufacture of Portland Cement with Observations on some of its Constructive Applications. New York, E. & F. N. Spon, 446 Broome street. 1877.

Q. A. Gillmore. On Limes, Hydraulic Cements and Mortars. Ninth edition. New York: D. Van Nostrand, 23 Murray street, 1888.

Anonymous. Manufacture of Cement at Folkstone: Scientific American Supplement, No. 350, September 16, 1882.

Reginald E. Middleton. Portland Cement; Its Manufacture and Uses. Scientific American Supplement, No. 386, May 26, 1883.

Mr. Watson. Portland Cement. Scientific American Supplement, No. 231, January 5, 1880.

Anonymous. Manufacture of Portland Cement. Scientific American Supplement, No. 84, August 11, 1877.

Q. A. Gillmore. Notes on the Hydraulic and other Cements at the Philadelphia Exhibition. Scientific American Supplement, No. 64, March 24, 1877.

Some account of the cement industries is given in the Mineral Resources of the United States, for 1883, pages 459 *et seq.*, and the statistics of the trade for 1887 are given in the same publication for 1887.

he has expressed himself briefly and to the point, and, unless otherwise credited, quotations are from Mr. Reid's book.

The object in writing this chapter is to call attention to the possibility of manufacturing artificial Portland cement in Arkansas. We have the chalk in abundance, and of good quality, and it is highly probable that a clay can be found suitable for mixing with it for the manufacture of this cement.

What is Portland Cement?—Portland cement is a product of hydraulic properties obtained by submitting to an intense heat, approaching vitrification, a mixture containing the proper proportions of carbonate of lime and clay. Now, clay consists essentially of silica and alumina. The changes which take place when a mixture of carbonate of lime and clay is heated to the verge of vitrification, may be briefly described as follows: The first effect of heat is, of course, to drive off any moisture contained in the mixture; next, the heat being increased, the carbonate of lime loses its carbonic acid, and lime is left; finally, when the heat is almost intense enough to vitrify the mass, the lime unites with the silica and alumina of the clay, forming silicate and aluminate of lime. This product, a mixture of silicate and aluminate of lime, is Portland cement. It is to the readiness with which these two compounds, silicate and aluminate of lime, unite chemically with water, forming extremely hard compounds insoluble in water, that the most valuable properties of Portland cement are due, namely, the properties of quicksetting, and durability in the presence of water. Of these two constituents of Portland cement silicate of lime is conceded to be the most important, and the one to which the hydraulicity of the cement is especially due.

The manufacture of Portland cement involves the following principal steps:

- I. The selection and estimation of the raw materials—the chalk and clay.
- II. Grinding and mixing the raw materials.
- III. Burning the mixture.
- IV. Grinding the product or clinker.
- V. Testing the cement.

THE RAW MATERIAL.

The Chalk.—The carbonate of lime used in the manufacture of Portland cement is derived from some form of limestone. Various hard limestones have been and are still used in the manufacture of such cement, but the softness of chalk, the fine state of division of its particles, the ease with which it is worked, and the little burning required to reduce it to lime renders it much superior to other forms of limestone for this particular purpose.

The high grades of Portland cement brought to this country from England are all made from chalk as the lime constituent.

The following table shows the composition of the chalk of Medway, England, used in the manufacture of the English Portland cement, and of a number of specimens of the Arkansas chalks. The analyses of the Arkansas material were made in the Survey's laboratory of material collected by the Survey :

TABLE OF ANALYSES OF ARKANSAS CHALKS.

LOCALITY.	Carbonate of Lime.	Carbonate of Magnesia.	Silica and Insoluble Silicates.	Silica.	Oxide of Iron.	Alumina.	REMARKS.
No. 81. Sec. 26, 11 S., 29 W.	94.18	1.37	8.49	.....	.....	.....	Water 0.55 per cent.
No. 82. Brownstown.	46.78	1.51	41.72. •	.....	4.86	1.41	Anhydrous.
No. 83. Rocky Comfort.	88.48	Trace	9.77	.....	.....	1.25	Anhydrous.
No. 84. Rocky Comfort, in gully 2 ft. below surface.	88.70	Trace	12.69	.....	.....	.....	Cream colored.
No. 85. Rocky Comfort, in gully 4 ft. below surface.	81.04	Trace	12.69	.....	.....	.....	Bluish; same locality as No. 88.
No. 86. Rocky Comfort, Sec. 27, 12 S., 32 W.	86.98	Trace	10.46	.....	.....	.....	
No. 87. Rocky Comfort, 1 foot below surface.	88.97	Trace	8.91	.....	.....	.....	
No. 88. N. E. ¼ of N. E. ¼ of Sec. 35, 11 S., 29 W.	95.29	Trace	.....	4.42	1.03	.21	
No. 89. White Cliffs Landing, top of cliff.	92.34	Trace	.....	.....	1.34	1.44	Light colored.
No. 90. White Cliffs Landing, top of cliff.	88.30	Trace	.....	7.76	1.26	2.58	Dark colored.
No. 91. White Cliffs Landing, top of cliff.	94.24	Trace	.....	3.34	0.89	1.80	
No. 92. White Cliffs Landing, base of cliff.	83.24	Trace	.....	10.85	1.97	3.02	
No. 93. White Cliffs Landing, base of cliff.	88.93	Trace	.....	46.13	3.76	7.56	
No. 94. N. E. ¼ of N. W. ¼ Sec. 25, 11 S., 29 W.	88.58	Trace	.....	5.45	1.05	2.82	Alkalies, 2.61.
Medway, England.							

NOTE: Except in Nos. 81, 82 and 83 the percentages are in terms of the chalk dried at 110 deg. to 115 deg. C.

The Extent of the Chalk Deposits of Arkansas.—The chalk deposits of the State, so far at least as the Geological Survey has been able to outline them, are confined to Little River county. It is highly probable, however, that similar or more or less modified deposits may be yet found in adjacent counties along the northeastern extension of the outcrop. The chalk is exposed at and about the village of Rocky Comfort and at and about White Cliffs Landing on Little river. The most extensive exposures are those about Rocky Comfort where the chalk and black soil derived from its decomposition cover an area of about twenty square miles. The chalk and the chalky limestones extend further north and further east than they are represented upon the map accompanying this volume, but they are covered in those directions by superficial post-tertiary deposits of clay, gravel and sands to depths which would probably render their handling unprofitable. Even the derived black soil is itself too thick in many places to admit of removal. The area over which the chalk is actually exposed and without covering about Rocky Comfort is estimated to be only about 900 acres.

At White Cliffs on Little river the pure white chalk covers an area of about 900 acres. Much of this area, however, has a covering of soil, gravel and cobblestones, although but little of it is thick enough to seriously interfere with the handling of the chalk.

The Clays.—Clay furnishes the other necessary ingredient, though not all clays are available for the manufacture of cement. The following table shows the composition of a number of the clays occurring both in the vicinity of the chalk deposits and in other portions of the State. But few of our clays and clay shales are included in this table, for the systematic study of these deposits has not yet been taken up by the Geological Survey. The composition of the Medway clay, that used in England, is also given for comparison :

TABLE OF PARTIAL ANALYSES OF ARKANSAS CLAYS.

LOCALITY.	Silica, Combined.	Sand.	Alumina.	Ferric Oxide.	Loss on Ignition.	Lime Mag- nesia, Alka- lies and loss.	REMARKS.
No. 52. Northwest $\frac{1}{4}$ of Sec. 17, 11 S., 32 W.	52.91	23.23	12.79	5.70	7.43	...	All the analyses are calculated in terms of the material dried at 110 degrees and 115 degrees C.
No. 53. Section 16, 12 S., 32 W.	63.16	19.94	7.43	2.00	6.57	...	
No. 54. Southwest $\frac{1}{4}$ of Southeast $\frac{1}{4}$ of Sec. 32, 12 S., 32 W.	34.07	48.63	8.11	5.63	8.87	0.89	
No. 57. Section 21, 12 S., 32 W.	49.27	23.71	17.14	5.62	5.67	0.90	
No. 58. Section 20, 12 S., 32 W.	33.15	46.48	7.13	5.53	9.24	0.97	
No. 59. Southwest corner of Sec. 32, 12 S., 32 W.	71.68	0.69	15.10	10.63	9.60	3.96	
No. 60. Hickory Slough, section 32, 11 S., 28 W.	32.83	34.86	13.34	5.33	4.41	...	
No. 62. Suburbs of Hope	70.01	1.81	8.41	3.91	2.59	...	
No. 63. Flat-woods, section 21, 11 S., 28 W.	69.25	4.62	14.94	5.54	4.54	2.56	
No. 65. Section 20, 11 S., 28 W.	42.67	35.67	10.21	5.75	5.18	...	
No. 66. Red Slough, section 32, 11 S., 28 W.	70.35	9.52	10.11	4.72	3.32	1.37	
No. 67. Southeast $\frac{1}{4}$ of Sec. 24, 11 S., 29 W.	66.03	6.81	17.52	5.47	8.66	2.18	
No. 68. Section 20, 11 S., 28 W.	61.61	5.70	16.19	6.78	6.41	0.01	
No. 69. Section 18, 11 S., 29 W., near Brownstown	71.36	7.71	10.53	5.27	4.43	3.31	
No. 70. Section 7, 11 S., 28 W.	66.67	1.08	16.67	7.71	6.58	2.29	

TABLE OF ANALYSES OF ARKANSAS CLAYS.

LOCALITY.	Silica.	Alumina.	Ferrie Oxide.	Lime.	Magnesia.	Manganese Oxide.	Potash.	Soda.	Loss on Ignition.	REMARKS.
No. 51. Johnson's bridge, near Dardanelle	56.91	19.80	6.68	4.76	0.96	Trace	2.12	1.05	9.57	Chocolate colored. Lime as carbonate.
No. 54. Johnson's bridge, near Dardanelle	74.46	11.58	7.52	0.64	0.26	0.41	1.10	0.64	4.11	Yellow clay, underlying No. 51.
No. 55. William's Lake, Little River county	58.24	13.22	9.25	4.55	4.19	.....	2.05	1.17	8.96	Part of the lime in the form of carbonate. Contains 1.01 per cent. of fine sand.
No. 110. Suburbs, south of Ft. Smith ("Nigger Hill")	58.43	22.50	8.96	0.32	1.14	.....	2.18	1.03	6.7	Carboniferous clay shale.
No. 71. Hardin & Boucher's quarry, Fort Smith	57.19	23.74	8.18	0.53	1.04	.....	1.53	0.87	7.21	Gray clay overlying the sandstone of quarry.
No. 184. Harding & Boucher's quarry, Fort Smith	65.12	19.05	7.66	.34	.31	.....	1.23	.85	6.12	Red mottled, overlying No. 71.
No. 98. Ketcham Iron Co's shops, Fort Smith	74.79	12.86	4.90	.35	.90	.....	1.73	1.49	2.91	
Clay of Medway, England	64.72	24.27	7.14	1.89	.....	.....	1.10	2.90	.....	
	70.56	14.52	8.04	4.43	.....	.....	2.05	1.90	.....	

Inasmuch as clays occur in almost every part of the State in greater or less abundance, it is assumed that the location of the chalk must determine the site of a possible cement factory. A special effort has therefore been made to ascertain whether the clays at and near the chalk deposits are available for the production of cement. The characters of the clays in the vicinity of the chalk are set forth in the table above. Little River and Sevier county clays are intimately associated with the post-tertiary gravels, and cover large portions, not of Little River and Sevier counties alone but of several of the adjoining counties in the southwestern part of the State. It is quite impossible to outline them here, even approximately, for they are exposed along the margins of the plateau gravel formation, and in a great many places those portions of the map represented as plateau gravel are simply the clays containing more or less pebbles, and usually separated from the bedrock of the region by a bed of cobblestones. Much of the area represented as bottoms or overflowed land is composed of sandy clays, known in places as "buckshot lands," though the "buckshot lands" are not confined to low elevations at all. Nos. 60 and 66 are from the overflowed lands of West Saline river, and may be regarded as fairly representing these soils as far as their adaptability to cement making is concerned.

All the clays of the region are more or less discolored at and near the surface. Where they have formed the bottoms of "sloughs," "slashes" or patches of ground under water for any considerable length of time they have been leached by acidulated waters until they are of a light gray color. On higher grounds they are usually discolored by the admixture of organic matter, while lower down they are mottled if on high ground, or filled with the characteristic "buckshot," or small nodules of iron, if upon low ground, while in their depths they may be red, yellow or buff colored.

Grinding and Mixing the Raw Material.—The two general methods hitherto employed in the manufacture of Portland cement are known as the "wet process" and the "dry process." In the former the materials are mixed with 60 to 70 per cent.

of water forming a thin mud or "slurry," this condition being produced for the purpose of properly mingling the particles of chalk and clay. After mixing the material is allowed to settle in large tanks, the water is drawn off, and the residue is dried, burnt and ground.

In the "dry process" the proportions of chalk and clay are determined by carefully weighing the material, which is then ground to a fine impalpable powder. This powder is then dampened just enough to allow the material to be formed into bricks and burned and then ground, in which condition it forms the cement of commerce.

Both the above processes have been successfully used, the "wet process" being the older one of the two. The "wet process" does not require so much capital in its operation, but its results are somewhat uncertain. The machinery required in the "dry process" is more expensive, but experience has shown that by it the results obtained are more certain, the process is more easily managed, the cement is more uniform in grade and is less expensive, and the results more satisfactory in every respect. In speaking of the methods of making cement therefore only the dry process need be mentioned. Just how the grinding of the chalk and clay is done is a practical matter of which it is scarcely necessary to speak further than to emphasize the indispensable necessity of the thorough grinding and intimate mixing of the ingredients.

A Blake crusher or some similar machine is used to crush the large lumps of chalk and clay; these are then put through another mill which further reduces the material, and it is then ground and thoroughly mixed on French buhrstones.

In the grinding our best authority on cement making seems to think it best that the chalks and clays or clay shales be ground separately and mixed in a double hopper as they enter the carrying screws leading to the brick mill.

Too much stress cannot be laid upon the mixing of the material before it is formed into bricks, for it is by bringing the lime and clay particles into close and intimate contact that in burning the silica and alumina form silicate and aluminate of

lime. After the grinding and mixing of the material it is dampened just enough to permit it to be pressed by a brick forming machine into bricks, and in this form it is burned.

Burning.—After the material is formed into bricks or other convenient masses they are arranged in kilns and burnt. Two general forms of kilns are used, the ordinary dome kiln and what is known in Germany as the Hoffman ring kiln. Both these forms are described by Mr. Reid in his work upon cement, pages 239 *et seq.* The ring kiln consists of a series of chambers in which the material is burnt, and which are heated one after another. In the ordinary dome kiln the contents, after burning, have to be left to cool before they can be drawn and the kiln recharged. In the ring kiln the process is continuous, and the excess of heat is utilized instead of being wasted.

The steps in the process of burning are :

First, the expulsion of the water remaining in the material.

Second, the driving off of the carbonic acid gas from the lime of the mixture.

Third, the fusion of the lime with the silica, alumina, iron and alkalis. This last step produces the clinker, which, being ground is Portland cement.

The three steps in this process require different temperatures, and it is essential that the temperature be under control during the entire process of burning, but especially is this necessary during its last stage. Mr. Reid says :

“The reactions take place at different temperatures, and provision should be made for a gradual raising of the heat in the order above referred to. It is most important, however, that the last and finishing stage in the application of heat for the clinkering should be capable of accurate adjustment. As the temperature required for this purpose is a high one (white heat), and converts the mass into a molten condition, care must be taken that it should neither last too long, nor be excessive in character, otherwise the product realized would be a glassy mass, incapable of being used for hydraulic purposes. In addition to this waste, the lining of the kiln would become

fused and amalgamated with its contents, so that the act of draining or emptying the kiln so improperly burned would entail great loss for structural repairs."

Grinding the Clinker.—The burned material is known as "the clinker." It should be more or less porous like lava, and of a greenish or brown color, but not a dark blue. This clinker after cooling is ground, first in a Blake crusher and afterwards in the other machinery used to prepare it for forming into bricks. In this condition it is packed in barrels for shipment.

Testing Cement.—When the cement has passed through the various stages of preparation given above, it should be subjected to such tests as may be necessary to determine whether or not it is capable of doing what will be required of it. Although testing is scarcely an essential part of the process of manufacturing cement, it is necessary to the reputation and success of an establishment making it that the precise nature of the product should be known and declared before it is put upon the market.

The following are the tests to be applied at the factory :

1st. If the clinker is brown and forms a dust freely, it is faulty and weak. If it is very dense and black, has no dust and yields a bluish gray harsh powder it should not be used until after long exposure. A good clinker should have a greenish tinge and yield a light gray powder which will set within half an hour after being used, and finally becomes extremely hard.

2d. The powder must have a certain degree of fineness. At least 75 per cent. of the whole should pass through a sieve having 2280 meshes to the square inch.

3d. A chemical analysis of the product should show its comparison with standard cements.

The following is an analysis of a good grade of English Portland cement :

Lime	60.05
Magnesia	1.17
Alumina	10.84
Silica	24.31
Alkalies	1.54

4th. The breaking or tensile strength of cement can be determined by moulding it into 8-shaped masses and ascertaining by the use of proper machinery, or even by weighing, the strain or tension these pieces will sustain. A good cement has a breaking strain of about 300 pounds to the square inch.

5th. The crushing strength of cement is tested by ascertaining the weight required to crush it, or its resistance to pressure. Various forms of machinery are used for this test, though simple devices may readily be planned.

The average crushing strength of cement, after six days in the water, is from 1400 to 2400 pounds to the square inch*

THE USES OF PORTLAND CEMENT.

Perhaps the principal use of Portland cement is for hydraulic mortar, but it is coming to be the principal mortar used in all kinds of masonry. Its great advantage over the ordinary lime and sand mortar lies in its settling firmly and at once. It is used in all kinds of concrete work, for making broad and smooth sidewalks, for artificial building stones, for large drainage pipes, for linings of cisterns. In the form of building stones this cement has been very extensively used in some parts of the world for ornamental purposes, for handsome residences, sea-walls, docks and other public works, and it has also been used successfully for paving blocks.

IMPORTS OF CEMENT AT NEW YORK, IN CASKS OF 400 POUNDS.

YEARS.	From Great Britain.	From European Continent.	Total Casks	Cost on Pier Per Cask.	Total Value
1882.....	171,202	190,924	362,126	\$ 2 60	\$ 941,528
1883.....	158,602	143,863	301,965	2 70	815,806
1884.....	155,477	201,085	356,562	2 50	891,405
1885.....	187,955	250,860	438,815	2 05	899,571
1886.....	261,464	301,887	563,351		
1887.....	432,327	385,903	818,230		

*Trautwine.

INDEX.

Ages of the different formations.....	179
Agricultural chalks and marls of Arkansas.....	231
population, value of marls to.....	193
use of marls.....	227, 239
Agriculture, methods of.....	222
relations to geology.....	192
Allen, David.....	237
Alluvial deposits.....	19, 20, 25, 203, 204, 205
classified.....	204, 205
of Southwest Arkansas, character of.....	203
soils, best kind of.....	206
Alpine, geology and topography of neighborhood.....	272
Ammonicardia.....	126, 135
Ammonia lost in decay of cotton-seed.....	251
Analyses of chalks.....	97, 160, 220, 221, 294
rocks and soils of Southwest Arkansas.....	220, 221, 235, 237
greensand marls.....	235
lime marls.....	237
Ancyloceras.....	76, 78
Anomia.....	76, 78, 82, 85, 135
Aporrhais.....	82
Arca.....	75, 78, 135
Arenaceous beds, the upper.....	72
of the upper cretaceous, extent of.....	99
Arkadelphia, High Bluff at.....	11, 14, 19, 40, 41, 73
section at.....	54
shales.....	33, 39, 53, 56, 72
shales, and cretaceous sands, unconformity between.....	54, 55
resting unconformably on Big Deciper formation.....	77
soils of.....	211, 212
analyzed.....	220, 221
Arkansas river, course of.....	15
red rises of.....	205
Arrangement of strata shown by cards.....	201
Artesian wells penetrating Camden series.....	49, 60
well, section of, near Okolona.....	278
Ash of plants, composition of.....	239, 243
percentage of, in dry plants.....	243
Asphaltum.....	231
Astarte.....	76
Atmospheric agencies, action of.....	26, 196
Austin, chalk of, analyzed.....	220, 221
Austin limestone, fossils of.....	93
Axinea.....	75
Baculites.....	73, 75, 76, 78, 100, 106
Basal tertiary, extent of.....	61
relations to Laramie beds.....	61, 62, 63, 64

Belemnitella	55
Belemnites	99
Benton group	68, 102
Bibliography of Portland cement	291
Big De Gray, a geologic boundary	269
Bingen sands	56
stratigraphy of	58
topography of	58
Bituminous shales	50
Black lands	7, 70, 85, 275
a confusing term	199
fertility of, near Dobyville	276
of Big Deciper formation	215
prairie	71
waxy prairie soil	217
Blue dirt, thickness of	80
marls	81, 82
at base of High Bluff, analyzed	220, 221
sands, described	77, 78
Bluff, section of, at paleo-neozoic contact	267
Bois d'Arc prairie	22
Bollman, Chas. H	261
Bones of Bromo-saurian	84
Bottoms	19, 47
dense forest growth of	275
Boulders, erratic, in Mississippi	45
Boundaries of neozoic area	24
Brackish water deposits of the eocene	63
Branner, John C	10, 55, 185, 261
Breaks, stratigraphic, in neozoic, evidence of	178
Breccia of fossil oyster shells	85
Bridge's plantation, blue marls on	81
Bromo-saurian bones	84
Brownstown marls	86, 87, 220, 221, 237
analyses of	220, 221, 237
thickness of	87
Buccinopsis	130
Building material	257
Burnet county, Texas, analysis of chalk from	160, 220, 221
Burning Portland cement	292, 300
Caddo creek a geologic boundary	266
Calcareous marls, value of, to agriculturists	193
Callianassa	73, 75
Callista	82
Calyptraphorus	59
Camden series, contacts with cretaceous	178
correlation of	60
description of	49
formation of iron-stone in	210
general conclusions on	59
penetrated by artesian wells	49
pyritiferous nodules in	197
scarcity of exposures of	49
section of	50
soils of	209

Camden series, the beginning of a long subsidence.....	183
thickness of.....	60
Camptonectes.....	78
Cannon, Dr., gravel terraces near house of.....	20
Caprina limestone.....	111, 156
Caprotina in flint nodules.....	162
Cardita.....	59
Cardium.....	75, 76, 82, 100, 134
Carrigan black land.....	33
Cassidula.....	76, 78
Cement, Portland, bibliography of.....	291
burning the material for.....	292, 300
crushing strength of.....	302
definition of "clinker" of.....	301
defined.....	292
grinding material for.....	291, 298
imports of.....	302
manufacture of.....	291
materials for.....	298
processes used in manufacture of.....	298, 299
testing the.....	292, 301
uses of.....	302
value of.....	302
Centre Point Gravel plateau.....	13
Chalk.....	70, 298, 295
agricultural use of.....	239
analyses of.....	97, 160, 220, 221, 294
and marls of Arkansas.....	231, 295
beds of White Cliffs, former extent of.....	88
Chalk beds of White Cliffs, fossils of.....	88
cliffs.....	42, 72, 78, 86, 87, 88, 97, 295
sub-chalk of.....	86
Comanche of Burnet county, Texas.....	114, 220, 221
deposits, profound subsidence during time of.....	102, 155
English.....	162
fallacies concerning.....	154, 161
flint nodules in.....	161
not a certain characteristic of.....	161
formation.....	13
geologic history of.....	157
gradation into calcareous sands.....	159
great extent of, in Texas.....	155
in Indian Territory.....	156
North American cretaceous.....	153, 160
metamorphism of.....	156, 167
nature of.....	154
of deep-sea origin.....	155
Europe, correlated by Meek and Hayden.....	68
White Cliffs, analyses of.....	237
relation of American to English.....	162
Rocky Comfort.....	35, 72, 89, 90, 91, 92, 94, 95, 97, 158
analyses of.....	97, 160, 207, 220, 221
use of, in agriculture.....	240
Chemnitzia.....	82

"Cistern rock"	78, 276
Cisterns, necessitated	271
Clark county marl, analyses of	237
mesozoic border, traced across	264
Mississippi marls, analyses of	235
sandy lands of	212
section of, littorals	79, 80
Clay, joint	81, 85, 274
Clays, analyses of	296, 297
economic use of	277
importance of	256
unchanged, in metamorphosed sandstone	274
Cleveland county red lands	58
relations to Claiborne formation	61
Clinker of cement	301
Coastal belt	2
plain, hydrography of	6
structure of	6
topography of	6
slope, features of	4
post-tertiary elevation of	184
Colors of soils due to iron	197, 277
Columbus-Marlbrook ridge	14
Comanche chalk, Burnet county, Texas	114
analyzed	220, 221
county soils, analysis of	220, 221
series, general remarks on	113
divisions of	110, 111
general description of	176
metamorphism of	114
prairies on	114
Composting, use of marls in	251
Conglomerate, ferruginous of plateau gravel	38
in process of formation	197
on bank of Wolf creek	280
Conrad, T. A.	83, 180, 171
Conspectus of neozoic formations	188, 189
Contacts between the neozoic systems	178
paleo-neozoic	7, 8, 9, 10, 24
Conus	82
Cook, Prof. G. H., on the use of marls	226, 233
Cope, Prof. E. D.	122
Copeland's ridge	52
Copeland's, Senator, marls at	87
Coquand, M.	131
Corbicula, described	134
(Astarte ?) pikensis, in the Trinity beds	134
Correlation of the Trinity	124, 125
lower cretaceous	176
Camden series	60, 61, 62
cretaceous	67
Cotton belt	5, 7, 48
cause of fertility of	15
topographic divisions of	7
production, report on	99, 221

Coulter's chalk bluff on Little river	112
Coulter's, D. B., plantation, black lands of	206
terraces on	20
Cragin, Prof. F. W., cretaceous area described by	115
Craighead's, J. A., asphaltum at	281
Crassatella	56, 76, 82
Craw-fish sands	119
Cretaceous, American, confusion concerning fossils of	164
correlation of, with that of Europe	108
Meek and Hayden's section of	68, 69, 70, 101, 102
Big Deciper beds of	55
close of, marked by a land epoch	183
contacts with the paleozoic	88
quaternary	71
tertiary	54, 55, 56, 178
group, coals in	66
defined	66
described	67
in Arkansas	66, 70
resume of	163
land barrier	101
later, relations of, to early tertiary	62
lower	110, 111
close of marked by land epoch and great disturbance	118, 183
lower concealed by quaternary	113
description and divisions of	110, 111, 112
Trinity division of	116, 117, 118, 119
marls of Arkansas	233
North American, chalk in	153
of America, confusion concerning	178, 174
correlation of, with European	108
of Eastern America a mere remnant	161
partial section of	54
sands at Washington	74
strata, cause of varying appearances of	69, 101
subsidence	109, 182, 188
upper, Texas region	98
series	70
equivalents of	70
divisions and beds of	72
general conclusions on and description of	96, 97
in Colorado	101
relations to other areas	98
to the Northwestern United States	101
Cross Timber sands, analysis of	97, 107
Cummins, Rev. W. F.	115
Dabney, Prof. Chas., on the use of fertilizers	280
Dakota beds	102
sandstone group	68
Dallas limestone	89
Deciper, Big, bluff on	52, 84
calcareous sands of	77, 78, 84
lake, conglomerate boulders on	198
De Gray, Big, horizon	81
Demarkation of cretaceous, tertiary and quaternary	24

Dentalium	76
Denudation of cretaceous strata	71
Dicotyledonous plants	59
Diller, Mr. J. S.	15
Dinosaurs	122
Dinosaur sands	127
Disintegration of neozoic beds	194
Divisions, natural, of the region	1
of neozoic region	5
Dome kiln in cement making	300
D'Orbigny	107
Dosinia	76, 82
Drainage system	14, 15, 16, 21
of east slope of Rocky Mountains	15
of the Ouachita	15, 17, 18
of Ouachita and Red rivers	16
Drainage tile, Major Ross's experiments with	256
Dried plants, percentage of ash in	243
Drillia	82
"Dry process" for cement	298, 299
Dumble, E. T.	29
Dunker, Dr. Wm	129, 134, 135
Dutton, Capt. Clarence E.	173
Eagle Ford shales	72, 97, 107
Eagle Pass region, union of cretaceous areas in	101
Eakin, Judge	74
Economic geology, introduction	191
products of the region	255
El Paso, <i>Exogyra costata</i> beds near	100
English chalks, analyses of	160
Eo-lignitic, extent of	62
relations to the Laramie	63
Erosion, line of, between quaternary, tertiary and cretaceous	54
Experimentation with Arkansas marls, necessity of	252
Experimental farm	253
<i>Exogyra costata</i> series, middle or marly beds of	181
related to green sand and chalk of Europe	181
<i>costata</i> and <i>E. ponderosa</i> , gradations between	168
absence of, from Northwestern upper cretaceous	101
clays	89, 73, 75, 76, 77, 78, 80, 88, 96, 97, described 166, 167
series the equivalent of the upper cretaceous of Europe	107
series, denudation of in Texas	101
development of in Texas	98, 100
general conclusions on	96
general description of	70, 96
metamorphism of	101
of Arkansas probably equivalents of the lower marl beds of New Jersey	106
table showing decreasing proportions of chalk in ascending order	13, 67, 70, 97
young of	102
gradation into <i>Gryphaea</i>	172
<i>ponderosa</i>	166, 167
marls	72, 78, 80, 81, 98
analysis of	97
lacking in New Jersey	105

Eutaw beds of Alabama.....	68, 104
Fall line of rivers	5, 6, 7
not a marked feature in Arkansas	7, 19
the head of navigation	7
Faunal breaks between the formations of the neozoic	178
Fertility of soils, how to increase	222, 223, 224
retain	246, 247
Fertilizers, proper method of using.....	244, 245
Ficus	100
First bottoms, origin of	203
Flatwoods	7, 43
identical with Prairie d'Ane.....	46
Flint nodules in chalk	161
Flood-plains	19, 20, 22
hardwood on.....	22
of Ouachita, Red and Arkansas rivers, difference of	204
Flora of the Eocene	63, 64
Foraminiferous chalk, decreasing in ascending stratigraphic order.....	97
Forbes, David, analyses by.....	160
Forests	255
Formations of the neozoic.....	179
Formations of the post-tertiary.....	28
Fort Pierre group	68, 94, 101, 102
Fossils characteristic of Rocky Comfort chalk.....	94
of upper cretaceous of Arkansas and lower marl bed of New Jersey	106
showing continuity of Arkansas cretaceous	82
the American cretaceous, confusion concerning	164
Fossil trees in bed of Big De Gray.....	267
Fox Hills formations.....	62, 101, 102
Fredericksburg division of the lower cretaceous	111, 112, 179
"Frog-levels"	20, 47
Fruit trees, soils for.....	234
Fusus	75, 76, 82
Gabb, W. M.	112
Garland, Gen.	74
Geologist, duties of, to agricultural interests	191
Geologist, State	10, 11, 36, 41, 175
Glacial currents	45
scratches, absent from Mississippi	45
Gladly lands of Union county, soil, analysis of.....	220, 221
Glauconite	34, 56, 72, 75, 88, 159
at Washington, analyses of	220, 221
metamorphosed beds of.....	99
oxidation of	197
Glauconitic marls.....	231
Gold, attempt to find, in pyrites	265
Grand Prairie, Prairie county, subsoil, analyses of	220, 221
Gravel plateau	11, 20, 40, 42, 79, 116
altitude of.....	40, 42
slope of	40
region, terraces of	20
source of	19
Great Northern lignite	61

Greensands	34, 56, 59, 68, 72, 75, 89, 96, 105, 159, 220, 227, 228, 229, 230, 233, 235
analyses of	220, 235
marls of New Jersey	105, 227, 228
uses of	227, 228, 229, 230
the Morris ferry	89, 220, 233
Grey Prairie, Arkansas county, subsoil, analyses of	220, 221
Grinding and mixing cement	292, 298
"Groups," use of the word	68
Gulf of Mexico, recession of waters of	25, 175
Gulf portion of the neozoic area divided	8
Gryphæa dilatata, identified by Marcou	172
gradation into exogyra	172
mutabilis	83
pitcheri	111
clay soils of	218
controversy concerning	163
described by Marcou	171
locality of	169
not found in the upper cretaceous	169
studied by Roemer	170
varieties of	171
vesicularis chalk marls	72, 75, 79, 80, 84
analysis of	97
vesicularis marl, Clark county, stratum, analyses of	220, 221
soil, analyses of	220, 221
vesicularis, young of	80, 102
vomer	75
Gypsiferous marls	12
nearness to chalk and greensands	240
Gypsum, beds of, in Southwestern Arkansas	240
Bluff, on Little Missouri river, near Murfreesboro.	19, 20
section of	119
consumption of, in 1886	241
supply at Plaster Bluff	257
uses of, in agriculture	241, 250
Hardwood on cretaceous soils	71
flood-plains	22
trees, value of	255
Hay, Dr. O. P., on the northern limit of the mesozoic	261
Hayden, F. V.	68, 70, 101, 102, 108, 130
Hearne, analysis of soils from	220, 221
Heilprin, Prof. Angelo	62
Henderson, Peter, opinions on fertilizers	223
Helioceras	93
Hemiaster	93
Hilgard, Dr. E. W.	43, 45, 46, 48, 60, 61, 70, 83, 85, 103, 104, 167, 242, 260
work of	242
High Bluff at Arkadelphia	11, 14, 19, 40, 41, 73
section of	73
blue marl, analysis of	220, 221
or Washington sands, soils of	213
process of formation of soils from	214
sands, analysis of	97
Hoffman kiln for cement	300
Hollywood marl, analysis of	220, 221

House, John, shales and sandstone near place of	271
Howard county, the mesozoic border across	284
Hummocks of the Prairie d'Ane formation	84
or second bottoms	47
Hygiene and disinfecting results of marling	250
Ideal agricultural marl, composition of	287
soil, composition of	242
Igneous area near Murfreesboro	197, 199
Impoverishment of soils	222
Improvement of soils	223, 224, 226
Injurious use of mineral waters	260
Inoceramus	55, 78, 75, 78, 93, 102
Inundation, alternating in neozoic area	25, 184
quaternary	47
Iron ores	256
"Iron pots"	39
Jaspery gravel, stratum of	34
Johnson county, Texas, soil analysis of	220, 221
Mr. L. C.	60, 104, 113
Joint clay	81, 85, 274
absence of fossils from	277
defined	274
Jones, Dr. B. F.	287
W. M., paleo-neozoic contact near house of	266
Jura-trias beds of Texas wanting in Arkansas	176
Kaolinitic orange sands	45
Kidd, Thomas	282
Kilns for cement making	300
Knowlton, Prof. F. H.	152
Koch, Dr.	84, 134
Kolb, J. I.	287
Lacustral deposits wanting	25
Lakes, absent from Southwestern Arkansas	16
Lamar county, Texas soil	220, 221
Lamna	76
Lampasas county, Texas, soil	220, 221
Land epoch, cretaceous time	63, 182, 183
Land plaster, use of	241
Laramie beds, transitional	62
relations to eocene	62, 63, 64
fauna missing in Arkansas	101
flora in the Camden series	101
Law of minimum	244
L' Eau Frais shales	56
formation of soil from	210
Legumen	75, 82, 100
Leidy, Dr.	84
Leptosolen	82
Lesquereux, Leo	64
Lignite	50, 51, 57, 59, 61
Lignites, analyses of	259
at the mouth of De Roche creek	53
formation of	60
of post-cretaceous land epoch	183
on Bacon's creek	283
shallow water origin of	59

Lime, application of	239
found at mouth of Caddo creek	265
marls, value of	236
table of analyses of	237
necessary to plant life	239
supply of, at White Cliffs	257
Limestone at C. B. McCauley's	269
containing tertiary fossils	53
Lingula	56
Little Missouri river, beds of marl, greensand and gypsum	17
navigability of	19
Little River county marl	235
navigability of	19, 42, 78, 87
system, fertility of its bottoms	17
Little Rock and Fort Towson road, as a geologic boundary	12
Llano Estacado	15, 43, 100, 200
Loess, Red river	29, 30, 31
distribution of, in Louisiana and Texas	30
Loughridge, Dr. R. H.	92, 99, 220
Lower cretaceous	67
correlated with the lower cretaceous of Europe	176
development of	110
divisions of	110
faunal break between it and upper cretaceous	110
Fredericksburg division of	11, 112, 179, 180
general description of	176
or Comanche series	110
resume	180, 181
Trinity division	116, 117, 118, 119
age of	179
Washita division of	111, 180
Lower cross timber sands	72
Lucina	76
Lupton, Prof. N. T.	241, 243
Lyell, Sir Charles	107, 108, 123, 159
Maestricht beds	107
Magnolia	64
Manchester landing, section at	52
Mansfield series like the Camden	60
Manures, necessity of experimenting with	253
necessary in agriculture	245
Marcou, Prof. Jules	108, 171, 172, 178
Marl, beds of, in <i>Exogyra costata</i> series	229
Marl-beds of New Jersey	70, 105, 106
Marlbrook-Columbus divide	33, 70, 84
Marling soils	225
Marls, analyses of	220, 221, 235, 237
bluish, methods of using	243
chalky	70, 84, 86, 97, 238
beds of	84, 238
classified	231
concluding remarks on	253
cretaceous	233
defined	225
improved by composting with lime	229

Marls, limited duration of effect of	246, 247
methods of using	242, 244, 246, 247, 248, 249
of Arkansas, proximity of the different kinds	232
proper to the different soils	252
tertiary	232
use of, in composting	251
value of, to agriculturists	193
Mastodon remains in Texas	178
McCaulley, C. B.	81, 269
McGee, W. J.	5, 6, 126
Medway, England, chalks of	294
clays of	297
Meandering of streams in neozoic area	195
Meek, F. B.	68, 101, 108, 130
cretaceous paleontology of	107
Melania	129
Mesozoic border across Clark county	264
Howard county	284
Pike county	278
Sevier county	287
northern limit of in Arkansas	261, 270
general features of	262, 263
Middle marl, Salem county, N. J., analysis of	235
Military road, as a geologic boundary	266
Mineral Springs	259
Mississippi beds, relations to Laramie	63
embayment defined	8
boundaries of	8, 62
report on geology of	62, 86, 103, 260
Missouri river, course of	15
Little, fertility of bottoms of	17, 204, 205
section at mouth of	51
of Gypsum Bluff on	119
Modiola	183
Morris Ferry greensands	89
Mortar made from calcareous clay	277
Morton, Dr.	170
"Mountain rocks"	12
Mulatto lands	217
Murfreesboro, igneous area near	197, 199
Nacodoches bluff	214
Nacotoch bluff	19, 74
Nashville, locality for experimental farm	254
Natica	83
Nautilus	78, 83, 93, 100, 102
Navarro beds	99, 100
fossils in, belonging to the Ripley group	100
Neocomian	179, 180, 227, 231
Neozoic addition	2, 3, 5, 8, 9, 10
area, stratigraphy of	25
contact with the paleozoic	53, 261, 284
deposits of Southwestern Arkansas, great erosion of	185
events recorded in	175
degradation of	186
demarkation in	27

Neozoic deposits, resume of.....	177, 178
stratigraphic breaks in.....	178, 185
formations, history recorded in.....	182
provisional conspectus of.....	188, 189
region, forces affecting topography of.....	194
of Arkansas and Texas, scientific interest in.....	186
relation to paleontologic mountain barrier.....	185
time, diagram, showing changes of level during.....	184
Neritina.....	129
Newberry, Dr. J. S.....	48
Niobrara group.....	68, 94, 102
Nodular concretions of iron ore.....	57
Northern border of mesozoic, general features of.....	262
lignite.....	61, 65
Nevaculite.....	53
Nucula.....	56, 75, 82
Okolona black lands, origin of.....	216
marl, analysis of.....	97, 237
Orange sands.....	43, 44, 45
Origin of "black lands".....	216
soils.....	192, 194
Oscillations, during neozoic time.....	184
Ostrea.....	56, 80, 98
cretacea (Owen).....	131
dubiensis.....	132
franklini, described.....	131
the only oyster found in the Trinity beds.....	132
larva.....	75, 76, 80, 85
laeviscula.....	98
multiformis.....	132
plumosa.....	83
Ostreidae, great variations of.....	165
table showing occurrence of in the mesozoic.....	166
Ouachita drainage system.....	15, 17, 18
mountain system, a geologic boundary.....	11, 113, 115, 175, 176
ancient beach at foot of.....	11, 32, 116, 124, 175, 176
described.....	10
erosion of.....	184, 185
extent of.....	175
river, alluvial soils of.....	204
changes in course of.....	195
flood-plain of.....	18
younger than the Red river.....	16
Owen, Dr. D. D.....	53, 119, 211, 216, 258, 283
Overdressing with marls.....	249
Pachycardium.....	75, 76, 99
Painted Caves, chalk at.....	156
Paleo-neozoic contacts.....	7, 8, 9, 12, 24, 53
Paleozoic contacts with neozoic deposits.....	185, 186
region.....	2
Panhandle of Texas.....	21, 29, 175
Papyridea.....	82
Pate's creek, section in valley of.....	76
Pebble beds of Alabama and Mississippi.....	44, 45
Pecten.....	75, 78, 80

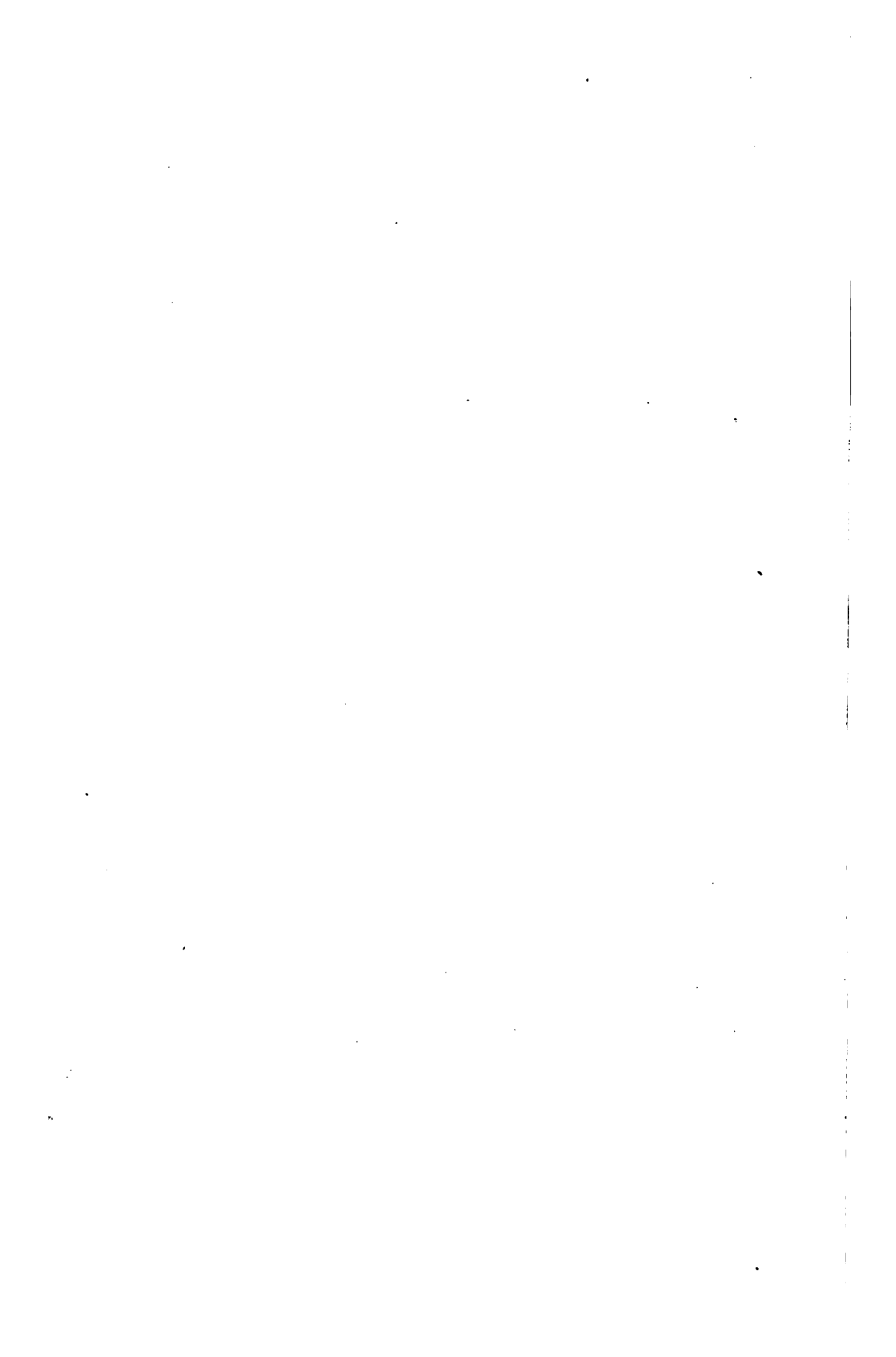
Peters, Dr. Robert, analyses by.....	218
Philadoma	82
Phosphatic marls.....	228
Piedmont plateau	5
southern homology of	7
Pike county, igneous outcrop in.....	197, 199
mesozoic border traced across.....	278
soils, analyses of.....	220
Pine lands of southern Arkansas on Camden series.....	59
on the cretaceous.....	264
trees characteristic of the tertiary.....	57
Pitcher, Dr.	170
Plant ash, composition of.....	239, 243, 244
Plaster bluff	40
Bluffs	19, 20
section of	119
of Paris, possible manufacture in Arkansas	258
Plateau of gravel, contacts with other formations.....	41, 42, 46, 71, 87
occurrence and nature of.....	35, 36, 37, 38, 40, 41, 43, 46
possibly synchronous with Llano Estacado.....	177
relations to Prairie d'Ane.....	46
Pleurocera.....	129
Pleurotoma	82, 100
Populus.....	64
Port Hudson formation.....	43
Portland cement. (See under "Cement").....	
Post-carboniferous formations.....	185, 189
Post-oak lands.....	217
Post-tertiary deposits, general divisions of.....	28, 29
formations, age of	28
soils of.....	208
resume of.....	177
Potatoes improved by the use of marls.....	229
Potomac beds.....	69
Potteries in Arkansas.....	256
Prairie de Roan.....	22
Prairie d'Ane	21, 22
contact of with Rocky Comfort chalk.....	35
or white clay till.....	32, 33, 34, 43, 70
possibly corollary phenomena with Port Hedson group	178
soils	207
Products, economic, of the region.....	255
Protocardium	75, 82
Pudding-stone of Wolf creek	280
Purbeck beds	179
Purpura.....	100
Quarry of sandstone.....	268
Quaternary beds of Mississippi	43
contact with tertiary	54
general conclusions on	43
resume of.....	177, 178
subsidence, destructive action of.....	184
Radiolites.....	84, 93, 102
Rainfall, effect on soils.....	194, 196
Rapa.....	82, 100

Raritan clays.....	68, 69, 106
Red lands	40, 41, 59
of Cleveland county, soil, analyses of.....	220, 221
residences built on	37, 213
soils of.....	208
methods of improving	208
Red river bottom soils, analyses of.....	220, 221, 297
cause of changes in course of	16, 195
course of	15
fertility of bottom lands of.....	205
indentation	8, 15, 21, 88
loess	29, 205
analyses of.....	220, 221
navigability of	19
older than the Ouachita.....	16
quaternary estuary of	32
sandstone and rock-salt, origin of	123, 124
Residual soil, Mark's place, Cleveland county, analyses of.....	220, 221
Residuary soils, character of.....	200
improvement of.....	225
"Rich woods," theories about the origin of.....	211
Riddell, Dr. W. P.....	99
Rimella.....	82
Ring kiln for cement.....	300
Rio Grande, course of.....	15
Ripley beds.....	68, 70, 103, 104
River system, as soil distributing agency.....	195
Roemer Dr. Ferd.....	70, 92, 94, 98, 167, 170, 176, 180
Rocks and soils, table of analyses of.....	220, 221
Rocky Comfort chalk.....	72, 89, 90, 91, 92, 95, 160, 186
analyses of.....	160, 220, 221
equivalent of the lower chalk of Europe.....	160, 181
former extent of	186
fossils characteristic of.....	94
of Texas, analysis of	220, 221
soils of.....	217, 218
uses of.....	92
Ross, Maj. Jesse.....	74, 77
experiments with drainage tiles.....	256
plantation, black calcareous loam on	206
Rotten limestone	68, 70, 77, 103, 104, 159, 275
lacking in New Jersey.....	105
of Mississippi, analyses of.....	237
Sabal	64
Salt manufacture in Arkansas.....	258
Sandstone quarries	268
Saurian remains.....	152
Scientific agriculture	222
Second blue dirt	79
bottoms	47, 48
Section of bluff at the paleo-neozoic contact	267
near crossing of Terre Noir.....	273
partial, of cretaceous rocks	271
Serpula	76, 135
Sevier county, mesozoic border traced across.....	287

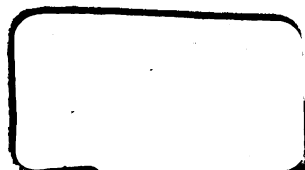
Shumard, Dr. B. F.....	70, 92, 93, 99, 100, 111
G. G.....	80, 81, 82, 99, 156, 157
Sloan's gin-house, section at	211
Slope of country changed.....	21
Smith, Dr. E. A	104
Soil, ideal, composition of.....	242
Soils, amelioration of.....	222
chemical action of atmosphere on.....	197
classification of	199, 200
distribution of.....	200
impoverishment of.....	222
mixing and marling of	225
of Big Deciper formation.....	215
marls on.....	215
Camden series.....	209
typical locality of.....	209
Rocky Comfort chalk.....	217
Southwest Arkansas, and of Texas, related to those of England and France.....	192
Trinity formation	218
origin of	192
qualities of.....	222, 223
residual of Southwestern Arkansas. erosion of.....	207
Spondylus.....	75
Stable manures in agriculture	245
Staked plains	15, 48, 100, 200
State Geologist.....	10, 11, 36, 41, 175
Strata, arrangement of, shown by cards.....	201
Stratigraphic breaks in neozoic	178
Stratigraphy, fundamental	24
Substructure, change in color of, on exposure	196
difficulty in determining	26
Succession of strata of the different formations	202
Superphosphates, use of	251
Synoptical table of formations.....	188, 189
Table of analyses of greensand marls.....	235
cretaceous formations.....	67
formations	188, 189
Ostreidae in mesozoic system	166
Teredo	79
Terraces	12, 20, 47, 48
Terrell, Texas, fossils found at.....	99
Terre Noir, origin of name	216
Tertiary	48
Camden series of.....	20
contact with the paleozoic.....	53
geology and paleontology, Hellprin	62
lignitic strata of	48
marls of Eastern Arkansas.....	232
structural character of.....	54
Texas cretaceous, typical section of.....	110
Thompson, Gilbert	5, 6
Tile, drainage, Maj. Jesse Ross's experiments with	256
Tillage, qualities of soils for.....	222, 223
Tilted strata, dip of.....	268

Tombigbee sands.....	68, 70, 94, 103, 104
relation to Rocky Comfort chalk.....	104
Topography of the neozoic region, forces affecting.....	194
Transported soils, character of.....	200, 203
Tree-culture.....	255
Trees, fossil, in bed of Big De Gray creek.....	267
Trichopteris.....	82
Trinity beds, at Tucumcarri mountain.....	122, 125
Ultima Thule.....	120
color of.....	123
origin of.....	123, 124
contact with the paleozoic.....	120, 121
with the upper Comanche series.....	121
extent of.....	118
fossil limestones of.....	118, 119
of near-shore origin.....	122, 176
of the Brazos valley.....	122
stratigraphic position of.....	123
thickness of.....	120, 123
division, age of.....	123, 124, 179
character and locality of.....	116, 117
color of soils of.....	218, 219
fauna of.....	127, 128, 185, 152
in Texas.....	121
of jurassic, or jura-cretacic age.....	124, 125
paleontology of.....	127
relation to other areas.....	125, 126, 127
Saurian bones in.....	117
vegetal remains of.....	152
vertebrates of.....	152
limestone, character of.....	117, 280
sands.....	38
absence of glauconite and chalk.....	117
Tucumcarri Mountains.....	172
Tuomey.....	44
Turner, Mr.....	273
Turritella.....	75, 76, 78, 82, 99
Ultima Thule.....	118, 120, 122, 216, 233, 258, 261, 280, 290
Upland portion of neozoic area.....	9
Upper cretaceous.....	67
a period of great subsidence.....	96
begun by a profound subsidence.....	182
differences in Arkansas, and the Mississippi-Alabama region.....	105
divisions of.....	71
ended by a gradual shallowing.....	183
extensive denudation of.....	72, 97
general conclusions on.....	96
relations to other regions.....	107
greensands, relation to the New Jersey greensand.....	105
of Arkansas, relation to the Texas region.....	98
relation of to Northwestern United States.....	101
to the Mississippi-Alabama region.....	102, 103
New Jersey area.....	105
resume of.....	177
soils of.....	213

Upper cretaceous, stratigraphic and lithologic characters of.....	96
table showing decreasing proportions of chalk in ascending order.....	97
thickness of in Arkansas and Texas.....	97
varying conditions of.....	180
Upper marl, New Jersey, analysis of.....	285
Uses of gypsum in agriculture.....	241
marls.....	227
Portland cement.....	802
Valley of Little and Red rivers.....	13
Vegetal, remains in the Trinity beds.....	152
Vegetation, effect on geologic structure.....	196
Vertebrae remains in the Trinity beds.....	152
Viala, Prof. Pierre.....	158
Vivipara.....	130
Volulithes.....	82
Walcott, Charles D.....	129
Ward, Prof. L. F.....	68
Washington, greensands at, analyses of.....	34, 214, 220, 221, 235
value of.....	284
or High bluff greensands.....	72, 76
rich in fossils.....	75
soils of.....	218
Washita division of the lower cretaceous.....	111
Wasting of lands, causes of.....	256
Waters, mineral, improper use of.....	260
unwholesome in blue clays.....	274
Wealden, resemblance in Trinity beds.....	128, 135, 179
Weems, D. L.....	286
"Wet process" for cement.....	298, 299
Whitfield, R. P.....	106, 136, 168
White clay till.....	29, 32
White Cliffs chalk, analyses of.....	160
of Little river.....	19, 42, 78, 87, 158, 159
White, Dr. C. A.....	64, 167, 169, 172, 180
Wilson, Mr., well-section on place of.....	279
Wolf creek a boundary of the mesozoic.....	279
Post-office, exposures of Trinity beds at.....	118
Wrightson, Prof. John, authority on agriculture.....	192, 200, 225, 244, 250
Yellow <i>Exogyra ponderosa</i> marls.....	72, 78, 80, 81, 98, 105
Yellow pines on cretaceous soils.....	264









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